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UPPER CRETACEOUS STRATIGR
ON THE WEST SIDE OF THE NORTHERN SAN JOAQUIN VALLEY, STANISLAUS AND SAN JOAQUIN COUNTIES, CALIFORNIA

SPECIAL REPORT 104
California Division of Mines and Geology
Sacramento, 1970

UPPER CRETACEOUS STRATIGRAPHY ON THE WEST SIDE OF THE NORTHERN SAN JOAQUIN VALLEY, STANISLAUS AND SAN JOAQUIN COUNTIES, CALIFORNIA

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ABSTRACT

Rocks of Late Cretaceous age crop out along the western side of the northern San Joaquin Valley. These rocks were first mapped and described by Anderson and Pack in 1915 and divided into the Panoche and Moreno Formations. Since then other workers have divided the rocks into groups, formations, and members.

A two-fold subdivision of the Panoche Formation can be recognized and mapped over a large part of the western side of the northern San Joaquin Valley. Further subdivision may be made locally, but rapid lateral lithologic variations and lack of diagnostic fossils make it difficult to recognize or map these smaller members for any appreciable distance.

Along Del Puerto Creek a section consisting of nearly 20,000 feet of marine Cretaceous rocks of the Panoche Formation is well exposed. These rocks are divided into seven units. The oldest is a dark greenish black shale ranging in age from the Lower Cretaceous Albian Stage to the Upper Cretaceous Turonian Stage. This unit is about 1500 feet thick and represents the lowermost of the two-fold subdivisions of the Panoche. It has been named the Adobe Flat Shale Member by Maddock (1964) and is correlative with the Pacheco Group of Taliaferro (1943, p. 131).

Units II through VII represent Taliaferro's Asuncion Group and are composed of light gray arkosic sandstones and medium brown siltstones and claystones and a lens of conglomerate. The sandstones and conglomerate were deposited by turbidity currents below wave base. Fossils present are characteristic of the Coniacian to Campanian Stages of the Upper Cretaceous. The upper gradational contact of unit VII with the overlying Moreno Formation marks the transition from a deep water to a shallow water environment.

The Moreno Formation is composed of brown clay shale and light gray sandstone. An upper sandy facies, the Garzas Member, can be recognized and mapped from Del Puerto Creek south to Garzas Creek. The Moreno, along the eastern flank of the Diablo Range, was deposited near shore in relatively shallow water. A land mass stood to the west and the deeper parts of the basins of deposition were to the east. Some of the sandstones of the Moreno Formation in the Del Puerto Creek area were deposited by turbidity currents. Foraminifera belonging to Goudkoff's D-1, D-2, and E zones occur in shales of the Moreno. Megafossils present are characteristic of the Campanian and Maestrichtian Stages of the Upper Cretaceous.

The biostratigraphic and lithologic equivalents of many of the subsurface units can be recognized in the surface exposures. The units encountered in the Shell Oil Company Elfers 36X-28 well can be correlated with a measured section of Upper Cretaceous rocks along Del Puerto Creek.

Three unconformities were recognized in the Upper Cretaceous sequence of this area. An understanding of these structural features helps explain some of the stratigraphic problems. Warping of the floor of the basin of deposition resulted in variations in the submarine topography. Because the sediments were deposited by turbidity currents, the topographically low areas were filled with coarse clastic material before the higher regions received any appreciable amount of sediment. Where these local structural irregularities can be recognized, it can be seen that some of the lateral facies changes are the result of local topographic relief.

The clastic material in most of the Panoche Formation was derived from a granitic and metamorphic terrain. The Campanian conglomerates in unit III contain Franciscan type rocks and were derived from a western land area. These conglomerates are younger than most of the conglomerates exposed to the south, particularly along Quinto Creek. Sandstones in units V, VI, and VII were deposited by turbidity currents moving in a northwest and southeast direction in the Del Puerto Creek area. Much of the sediment was derived from the west and much of this probably represents reworked Upper Cretaceous sedimentary rocks. The location of the source area of the granitic and metamorphic rocks could not be determined from the study of this limited area.

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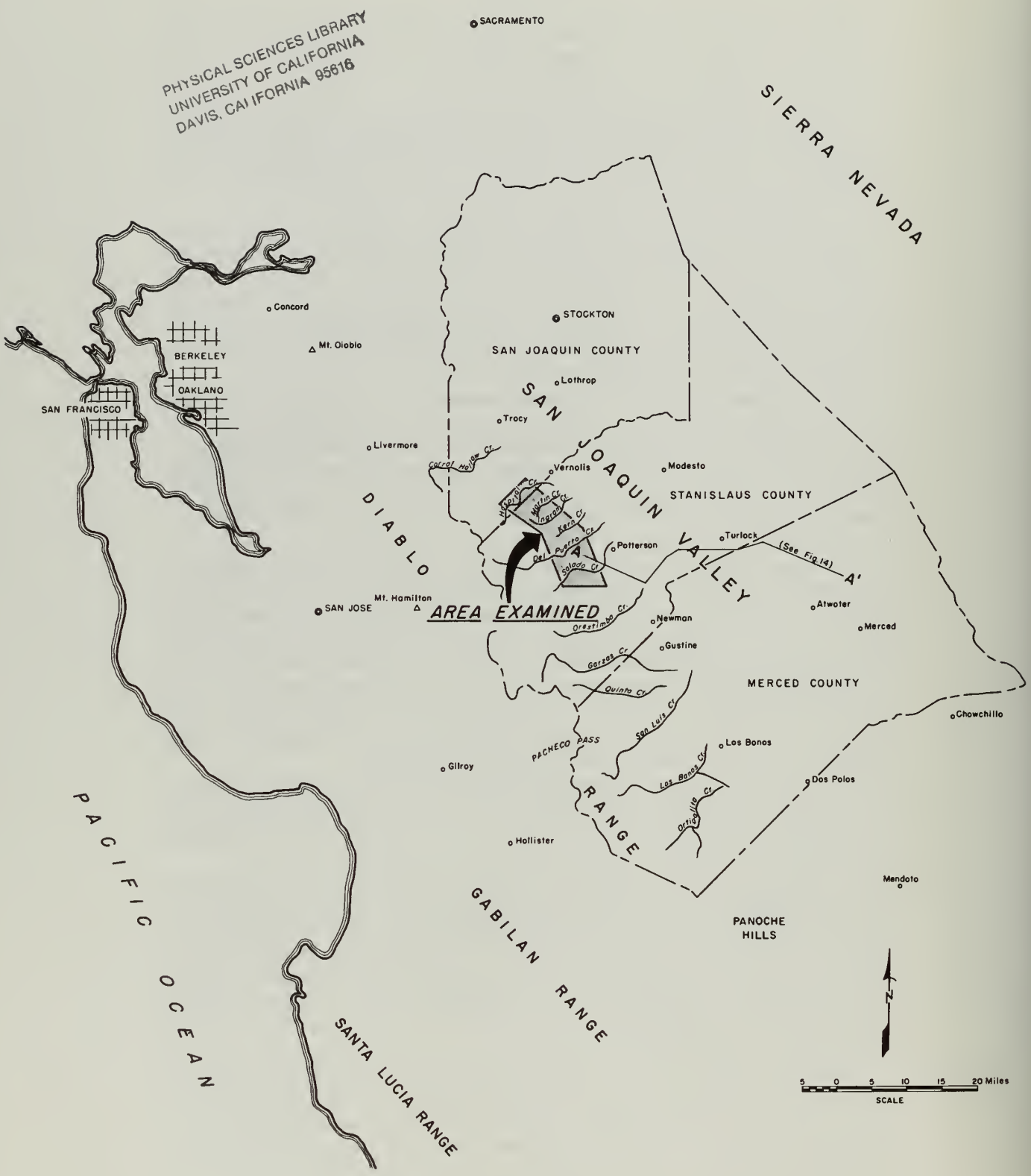

Figure 1. Index map.

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UPPER CRETACEOUS STRATIGRAPHY ON THE WEST SIDE OF THE NORTHERN SAN JOAQUIN VALLEY, STANISLAUS AND SAN JOAQUIN COUNTIES, CALIFORNIA

By CHARLES C. BISHOP

INTRODUCTION

The purpose of this paper is to describe the lithology, discuss some of the stratigraphic and structural relationships, and to correlate the surface outcrops of the Upper Cretaceous sedimentary rocks with their subsurface lithologic and biostratigraphic equivalents in the northern San Joaquin Valley.

The area studied is located in central California, south of Tracy, in San Joaquin and Stanislaus Counties (fig. 1). The surface outcrops were studied in detail along the western border of the northern San Joaquin Valley between Salado Creek and Hospital Creek, and several reconnaissance trips were taken both to the north and south of this area. The area of interest extends eastward from the surface outcrop into the San Joaquin Valley, where Upper Cretaceous rocks are encountered in most of the wells drilled for oil and gas. Three gas fields are now producing in this area: Vernalis in T. 3 S., R. 6 E., McMullan Ranch in T. 2 S., R. 6 E. and Lathrop in T. 1 S., R. 6 E. The Tracy gas field in T. 2 S., R. 5 E. produced for a number of years but is now abandoned. All of these fields have produced natural gas from rocks of Late Cretaceous age. Strata equivalent in age to these producing zones and earlier Upper Cretaceous rocks crop out as a northwest-trending homocline with steep northeast dips generally between 50° to 65°, along the western border of the valley. Exposures are excellent, particularly along the major drainages.

The author would like to express his appreciation for the paleontological support rendered this project by the following people: Andrew C. Marianos, Humble Oil Refining Company; William E. Evitt, Professor of Paleontology, Stanford University; Charles W. Carey and Alvin A. Almgren, Union Oil Company; Edwin H. Steinmeyer, Shell Oil Company; David L. Jones, U. S. Geological Survey; Joseph C. Peck, University of California, Berkeley; LouElla R. Saul and Willis P. Popenoe, University of California, Los Angeles; and Richard B. Saul, California Division of Mines and Geology. The writer is also indebted to Robert Hoffman and Otto Hackel for supplying valuable subsurface information and to Allan Bennison who accompanied the author in the field on several reconnaissance trips.

Application of Paleontology

In applying the European stages to the Cretaceous rocks of the northern San Joaquin Valley the writer has followed the work of Popenoe *et al.* (1960) and Matsumoto (1960) unless otherwise stated. Popenoe's chart is also followed in correlating the European stages with the foraminifera zones of Goudkoff (1945).

Although the author has followed Goudkoff's zonations of the Upper Cretaceous, he has applied them as modified by various paleontologists in the past twenty years. To the author's knowledge there is no paper published to date, formally modifying the original work. For the purpose of this paper the following foraminifera are used to identify Goudkoff's zones referred to herein:

C and/or D-1 zone	*Bulimina prolixa*
D-1 zone	*Bulimina prolixa* in association with *Siphogenerinoides clarki*
D-2 zone	*Bolivina incrassata*
E zone	*Planulina constricta* (*Anomolina henbesti*)

Where foraminifera other than the above were present and used for zoning, these are listed, along with the qualifications made by the paleontologist who examined the samples; for example, "probably D-2" or "possibly E zone".

Three major problems concerning Goudkoff's zonations encountered by the writer are listed below. No attempt is made herein to resolve these problems, as they are within the scientific discipline of paleontology and beyond the scope of this paper.

1. Goudkoff (1945 p. 993) defines the H zone in part as ". . . the lowest 5425 feet of beds exposed in Ingram Creek. . . ." Mapping and megafossil evidence strongly indicates that most of the lower 5425 feet of Cretaceous sedimentary rocks in Ingram Creek are no older than Campanian, whereas Goudkoff's H zone is considered to be Cenomanian (Popenoe *et al.*, 1960, Chart 10).

2. Goudkoff (1945 p. 965, Figure 4) considers sandstones of the Panoche Formation in Hospital Creek to be F-1 zone. Both in Hospital Creek and Ingram Creek, samples collected several hundred feet below the top of the Panoche contain *Planulina constricta,* indicating the upper Panoche sandstones to be E zone.

3. Goudkoff (1945 p. 991) states that the interval 6900 feet to 8900 feet in the Amerada Petroleum Corporation F.D.L. well #1 at Tracy has the best foraminiferal material characteristic of the F-1 zone, and the interval 8900 feet to 9431 feet has a good fauna of the F-2 zone. These intervals are now con-

sidered by many paleontologists to be E zone. A brief discussion of this problem appears in the August, 1964, issue of the *Pacific Petroleum Geologist* in a criticism by H. H. Sullwold and reply by W. F. Edmondson, D. C. Callaway, R. D. Hoffman and R. A. Teitsworth.

Review of Stratigraphic Problems

With the exception of the obvious difference between the shales of the Moreno Formation and the sandstones of the Panoche Formation (Anderson and Pack, 1915), the 25,000 feet and more of Upper Cretaceous rocks at first appears to represent a monotonous conformable sequence of alternating sand and shale units. Closer examination of the outcrop along any particular drainage reveals otherwise. The rocks may be divided into several distinct major lithologic units, and these in turn may generally be subdivided locally into individual members. However, it is impossible to map laterally and extend these smaller subdivisions for any appreciable distance because of rapid lateral variations in lithology, buttressing, and overlapping. Lack of fossils and time transgression of rock stratigraphic units complicate correlations. In fact, except for the major units, it is often difficult to trace or correlate the rocks that crop out in one canyon with the rocks exposed in another canyon only a few miles away. This problem was noted by Briggs (1953a, p. 421), who states:

> Eight formatianal units of Bennison (1941) within the Late Upper Cretaceous section in the region immediately north af Pacheca Pass cauld not be recagnized beyand Ortigalita Creek, approximately 10 miles south of the pass. M. B. Payne's (1941, 1951) eight divisians af the Moreno Shale are nat distinctive units narth and sauth of the Panoche Hills, the type area. J. Q. Anderson distinguished eleven members in the southern part af the Diablo Range; but these have never been succéssfully traced north af that area, and of more than fifty cartographic units mapped by the writer between Little Panache and Los Banas creeks (Briggs, 1953, pl. 1) none is certainly continuaus acrass the 17 miles between these creeks. These abservations indicate abrupt lateral and vertical changes . . . that are characteristic of these rocks throughaut the Coast Ranges.

Because of these rapid lateral variations, some of the attempts to subdivide the Moreno and Panoche Formations, rather than clarifying, have led to confusion in the usage of these rock stratigraphic units. For example, Payne (1962, p. 175) states that ". . . there is probably very little or no true Moreno shale north of Los Banos Creek in the exposed outcrop." In a time-stratigraphic sense this statement seems quite true, for the Moreno shales north of Panoche Pass are somewhat older than the type Moreno in the Panoche Hills. Nonetheless, the Moreno Formation as originally mapped by Anderson and Pack (1915) as a rock stratigraphic unit is one of the most easily recognized and lithologically distinct units within the Upper Cretaceous of the Diablo Range. For this reason the term Moreno Formation has been retained in this report and is used as originally mapped by Anderson and Pack. However, because of rapid facies changes and the overall time transgression of the unit, no attempt has been made to relate the subdivisions of the Moreno in the Panoche Hills described by Payne (1941) to the formation in this area.

Review of Nomenclature

An understanding of the development of the Cretaceous nomenclature in California and along the Pacific Coast is helpful as a background to any study of this series of rocks. Jenkins (1943) and Popenoe *et al.* (1960, p. 1492–1504) give very comprehensive discussions of this history and for this reason it seems unnecessary to repeat it here. The following review is intended to give the reader a generalized background of the Upper Cretaceous nomenclature as it has been developed in the eastern Diablo Range, particularly north of Pacheco Pass.

The Cretaceous of the eastern Diablo Range can be divided into three or four major units, which have distinctive lithologic characteristics and/or contain representative faunas that can be recognized over large areas. It is on these major subdivisions that the earlier workers based the nomenclature discussed below. This nomenclature, as interpreted by the writer, has been related to outcrops exposed along Del Puerto Creek (see figure 2).

Anderson and Pack (1915) designated the Upper Cretaceous as the Chico Group and divided it into two units, the Panoche Formation and Moreno Formation. It was recognized at that time that some Lower Cretaceous was included in the Panoche Formation, particularly in the Tesla area and possibly in other places as well, and it has since been shown that there are several areas in which Lower Cretaceous and possibly Upper Jurassic rocks occur in the Panoche (Taliaferro, 1943, p. 130).

Taff (1935, p. 1088–89), working in the Mt. Diablo area, restricted the Panoche Formation to the upper part of the Panoche of Anderson and Pack (1915). He applied the term Chico Formation to the lower olive drab shales and sandstones that belong to the upper Albian, Cenomanian and Turonian Stages according to F. M. Anderson and Hanna (1935, p. 16 and 18). The Moreno Formation was unchanged.

F. M. Anderson (1943) proposed Chico Series to include all of the Upper Cretaceous and divided it into the Pioneer Group, Panoche Group and Moreno Group. The Panoche Group corresponds to the Panoche Formation of Taff, and the Pioneer agrees roughly with Taff's Chico Formation. The Moreno Group was the same as the Moreno Formation of Anderson and Pack (1915).

Taliaferro (1943, p. 130–134; 1944, p. 471–474) objected to the continued use of the term "Chico" because of the many different ways in which it has been used in the past. He proposed that the Upper Cretaceous of the Coast Ranges including the eastern Diablo Range be divided into two groups: the Pacheco Group and the Asuncion Group. The Pacheco Group was the Lower Cretaceous upper Albian and Upper Cretaceous Cenomanian and Turonian beds in Quinto and Garzas Creeks in the Pacheco Pass quadrangle. The name was also applied to the lateral extension of these beds in a continuous outcrop belt both north and south and to rocks in a down-faulted syncline to the west of this belt along "El Puerto Creek". Taliaferro subdivided the Asuncion Group

COMPARATIVE NOMENCLATURE CHART (OLDER UNITS ← → YOUNGER UNITS)			AUTHORITIES
KNOXVILLE? FORMATION[4]			
ADOBE FLAT SHALE MEMBER	PANOCHE FORMATION	MORENO FORMATION	MADDOCK (1964) (MT. BOARDMAN QUADRANGLE)
PACHECO GROUP	LOWER ASUNCION GROUP	UPPER ASUNCION GROUP	F.M. ANDERSON (1958) (EASTERN DIABLO RANGE)
	PANOCHE FORMATION	MORENO FORMATION: MUSTANG, QUINTO, GARZAS (VOLTA)[3]	
HORSETOWN FORMATION[2]	PANOCHE FORMATION	MORENO GRANDE FORMATION	HUEY (1948) (TESLA QUADRANGLE)
PACHECO GROUP	ASUNCION GROUP		TALIAFERO (1943) (EASTERN DIABLO RANGE)
	PANOCHE FORMATION	MORENO SHALE; GARZAS SANDSTONE	
CHICO SERIES			F.M. ANDERSON (1943) (EASTERN DIABLO RANGE)
PIONEER GROUP	PANOCHE GROUP	MORENO GROUP: MORENO, QUINTO, GARZAS	
CHICO GROUP			TAFF (1935) (MT. DIABLO AREA)
CHICO FORMATION	PANOCHE FORMATION	MORENO FORMATION	
CHICO GROUP			ANDERSON AND PACK (1915) (WEST SIDE SAN JOAQUIN VALLEY)
PANOCHE FORMATION		MORENO FORMATION; U. SOST. MBR.	
PANOCHE FORMATION		MORENO FORMATION; GARZAS MEMBER	SUBDIVISIONS OF THE CRETACEOUS ALONG DEL PUERTO CREEK AS USED IN THIS REPORT
ADOBE FLAT SHALE MEMBER	II, III, IV, V, VI, VII		
H, G-2	G-1 ZONE; F-2 ZONE; F-1 ZONE; E ZONE	D-2 ZONE; C AND/OR D-1 ZONE	GOUDKOFF[1] (1945)
ALBIAN-TURONIAN	CONIACIAN-SANTONIAN; CAMPANIAN	MAESTRICHTIAN	EUROPEAN STAGES
LOWER CRET	UPPER CRETACEOUS		SERIES

1. Goudkoff's zones are applied to the subdivisions of the Upper Cretaceous from evidence obtained from microfossil localities in this area of this investigation.

2. Huey (1948) referred the Lower Cretaceous, Albian Stage rocks in the Tesla quadrangle to the Horsetown Formation.

3. The "Volta Sand" of Bennison referred to by Anderson (1958) is probably not present in the Del Puerto Creek area.

4. Although Upper Jurassic "Knoxville" beds are probably present at several localities in the Eastern Diablo Range, they are probably absent in the area covered by this report.

Figure 2. Comparison of nomenclature. The chart compares the subdivisions of this report with the nomenclature used by previous workers for the Cretaceous rocks exposed along the west side of the northern San Joaquin Valley.

into the Panoche Sandstone, Moreno Shale and the Garzas Sandstone. "The exact limits . . . are not known but the group is believed to represent all of Cretaceous time after the Turonian." (Taliaferro, 1943, p. 133).

Huey (1948) divided the Cretaceous of the Tesla quadrangle into Lower Cretaceous Horsetown Formation and Upper Cretaceous Panoche and Moreno Grande Formations. Except for the differentiation of the Horsetown at the base, Huey's Panoche Formation is the same as Anderson and Pack's (1915). Huey's Moreno Grande Formation is the same as the Moreno Formation as originally mapped by Anderson and Pack (1915) north of Pacheco Pass. The term Moreno Grande was used to signify greater or enlarged Moreno. Huey (1948, p. 31) explains this as follows:

> The present writer in 1936 and again in 1940 followed Anderson and Pack in calling these beds Moreno. Since that time his work in other parts of the Diablo Range along the west border of the San Joaquin Valley and the contributions of other geologists, indicate clearly that the Moreno as originally mapped is more inclusive than the Moreno as originally defined, and that some clarification of the stratigraphic relationships of the Upper Cretaceous in this region is needed . . . North of Pacheco Pass the Moreno Grande comprises what Anderson and Pack mapped as Moreno . . . Southward to the Coalinga region the Moreno Grande includes the restricted Moreno, the Brown Mountain sandstone and the *Pachydiscus* silt as members. The top of the underlying Joaquin Ridge sandstone member of the Panoche in this southern area correlates approximately with the top of the Panoche as mapped by Anderson and Pack in the area north of Pacheco Pass.

This relationship was illustrated by Goudkoff (1945, p. 962, fig. 2).

F. M. Anderson (1958) retained Taliaferro's Pacheco Group but divided his Asuncion Group into an upper Asuncion Group and a lower Asuncion Group. The location of the contact between the Pacheco Group and the lower Asuncion Group is well-defined by fossil localities along Quinto Creek (p. 31), but the boundary between the lower and upper Asuncion Group is somewhat vague. From inference (p. 56–57), the writer interprets it to be at the contact between the Moreno and Panoche Formations of Anderson and Pack in the area north of Pacheco Pass. In this area the upper Asuncion Group includes the subdivisions of the Moreno suggested by Bennison (1940).

In descending stratigraphic order these are listed by Anderson (1958, p. 56) as follows:

1. Volta Sand
2. Garzas Sand
3. Quinto Silt
4. Mustang Shale

Unfortunately neither Taliaferro nor F. M. Anderson published maps with their papers. Allan Bennison has kindly supplied the writer with a copy of his unpublished mapping of the Cretaceous outcrops in western Merced County. Bennison divides the uppermost Cretaceous strata (the Moreno Formation of Anderson and Pack) into four units. In descending order these are the Garzas Sand, the Quinto Silt, the Brown Mountain Sandstone and the Mustang Shale. The Volta Sand is not shown. This four-fold division of the Moreno Formation can be recognized as far north as Del Puerto Creek (fig. 15).

Maddock (1964), in the Mount Boardman quadrangle, retained the Panoche and Moreno Formations of Anderson and Pack, but recognized a thin sequence of Upper Jurassic shales near the base which he designated Knoxville (?) Formation. A sizeable shale unit at the base of the Panoche Formation was designated the Adobe Flat Member. This member is believed by the writer to be equivalent to Taliaferro's Pacheco Group.

Methods of Presentation

The Upper Cretaceous rocks along the west side of the northern San Joaquin Valley can be readily divided into three major lithologic units. These units, as designated in this report, are the Moreno Formation (including the Garzas Member), the Panoche Formation, and the Adobe Flat Shale Member of the Panoche Formation. Further subdivisions can be made along any one particular outcrop section, but because of rapid lateral variations, these smaller subdivisions generally can not be traced for any appreciable distance (pl. 1). For this reason, only the rock units exposed in the vicinity of Del Puerto Creek (pl. 2) are described in detail in the text. Del Puerto Creek was chosen because the rocks exposed are typical of the Cretaceous rocks of the eastern Diablo Range and represent one of the most complete, well exposed, and readily accessible outcrop sections in the area. Columnar sections along Ingram and Hospital Creeks are presented for comparative purposes.

The nomenclature of the formations used herein is the same as that of Anderson and Pack (1915). The Garzas Member of the Moreno Formation and the Adobe Flat Shale Member of the Panoche Formation (Maddock, 1964) are named subdivisions. The balance of the Panoche Formation has been subdivided into six informal units.

The relationship of the subsurface units used by Calloway (1964), Hoffman (1964) and Teitsworth (1964) to the rocks exposed along Del Puerto Creek is shown by the correlation of the outcrop with the Shell Oil Company well, Elfers 36X-28 (fig. 15). This well is located about one mile south of Del Puerto Creek in Section 28, T. 5 S., R. 7 E. (pl. 1).

In the Del Puerto Creek area the writer was unable to recognize with certainty the 10 named subdivisions of the Panoche Group described in the Panoche Hills by Payne (1962). Therefore, they have not been used in this report.

LITHOLOGIC DESCRIPTIONS AND PALEONTOLOGY

Panoche Formation

ADOBE FLAT SHALE MEMBER (UNIT 1)

The Adobe Flat Shale Member of the Panoche Formation was named and described by Maddock (1964). The type area occurs in a downfaulted syncline two to three miles southwest of the outcrops described here. In Del Puerto Creek this member overlies the Franciscan Formation and is composed of approximately 1800 feet of dark brownish gray to black, thinly bedded, silty, hard, brittle clay shales that have a characteristic greenish cast. Calcareous concretions and lenses of impure limestone several inches thick are common (fig. 3). Light brown phosphatic material is sometimes associated with the limestone lenses and the calcareous concretions. Thin, fine-grained, silty sandstone interbeds occur a few hundred feet above the base. Petrified wood is associated with the sandstones, and carbonaceous material occurs in the shales.

The Adobe Flat Shale Member is in fault contact with the Franciscan Formation and is overlapped by younger sedimentary rocks about one mile north of Del Puerto Creek. Its outcrop extends southward for about four miles, where it is again overlapped for a short distance by younger rocks before it reappears and continues southeastward across Quinto and Garzas Creeks (Maddock, 1964; Schilling, 1962). Along Quinto Creek, ammonites suggestive of the middle and upper Turonian Stage have been collected from beds near the top of this member. (Matsumoto, 1960, p. 51, 85, 87 and 88).

The lower few hundred feet of shale along Del Puerto Creek was assigned to the Knoxville (?) Formation by Maddock (1964). This shale has a physical resemblance to shale to the southwest in which Maddock recovered *Buchia piochii* (Gabb). The writer collected *Buchia* of Early Cretaceous age (Jones, D. L., personal communication, 1966) in the Quinto Creek area (about 20 miles to the south of Del Puerto Creek) within concretions of a similar appearing shale directly above the Franciscan contact. Shale beds containing a *Buchia* fauna have been reported from several localities directly overlying the Franciscan Formation along the west side of the San Joaquin Valley (Schilling, 1962; Enos, 1965, p. 5; Bennison, personal communication, 1966). A phosphatic calcareous concretion from shale about 140 feet above the contact with the Franciscan Formation along Del Puerto Creek was found to contain Lower Cretaceous dinoflagellates, which probably belong to the Albian Stage, according to William Evitt (personal communication, 1966).

A series of interbedded greenish shale and sandstone similar in lithology to the rocks along Del Puerto Creek overlies the Franciscan Formation along Hos-

Figure 3. Phata af Limestane Lenses and Calcareous Cancretians, Adabe Flat Shale Member. The rocks are in the Panache Farmatian alang Del Puerto Creek.

pital Canyon. The writer and Richard B. Saul collected ammonites from DMG locality #5. These fossils were identified by Joseph H. Peck, Jr., as *Beudanticeras (Brewericeras) hulenense* (Anderson) and *Leconteites* cf. *L. lecontei* (Anderson) and are Lower Cretaceous, Albian Stage (Matsumoto, 1960, p. 146). Also along Hospital Creek Goudkoff (1945, p. 993), reports the occurrence of the Foraminifera *Cibicides stephensoni* (*Planulina pseudoconstricta*) ". . . in beds exposed about 10,000 feet below the Moreno as mapped by R. Anderson and Pack." The occurrence of this species, indicative of the G-2 zone of Goudkoff, considered to be Turonian Stage by Popenoe *et al.* (1960), has been reported by others as occurring about 1,800 feet above the contact with the Franciscan (Charles Cary, personal communication, 1964). These two localities are separated stratigraphically by less than 400 feet. Samples of shale collected by the writer along Hospital Creek, 1,700 to 1,900 feet above the contact with the Franciscan Formation, contained a pollen and dinoflagellate assemblage diagnosed as Upper Cretaceous (Evitt, written communication, 1965) and Foraminifera identifiable only as pre-Campanian (Andrew W. Marianos, personal communication, 1964). Along Del Puerto Creek, west of the rocks studied in this paper, Maddock (1964) reports: "Shales within 300 feet stratigraphically above the base of the Adobe Flat Member contain *Inoceramus labiatus* of early Upper Cretaceous (lower Turonian) age."

On the basis of the similarity in lithology and age, the writer correlates the Adobe Flat Shale Member in the Del Puerto Creek area with the sandstones and shales that directly overlie the Franciscan Formation and comprise the lower 2,800 feet of Cretaceous rocks that crop out along Hospital Creek. The member ranges from Lower Cretaceous Albian Stage to Upper Cretaceous Turonian Stage.

UNIT II

Unit II is the next most obvious subdivision of the Panoche Formation along Del Puerto Creek. It is composed of approximately 4500 feet of thinly bedded brown claystones and siltstones, and contains a few interbeds of fine-grained arkosic sandstone in the upper 2500 feet. The brownish color of the claystones and siltstones is distinctly different from the dark gray and green of the underlying Adobe Flat Shale Member and is more closely related in appearance to the overlying units of the Panoche Formation.

A mile or two north of Del Puerto Creek, unit II is faulted against the Franciscan Formation and overlapped by younger beds. Though probably present, it was not recognized as a distinct unit along Hospital Creek. Southward the unit becomes sandier, and interbeds of conglomerate are numerous.

Several fossil localities occur within unit II south of Del Puerto Creek. LouElla Saul examined the material from three of these localities, UCB-761, 765 and

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Figure 4. Photo of Conglomerate Beds of Unit III Along Del Puerto Creek. The pebbles are imbricated above the points of the pick and the pencil, indicating current direction from upper left to lower right (west to east). The crude graded bedding of the conglomerate shown here is better developed in adjacent outcrops.

766 (Maddock, 1955). All the fossils were contained in boulders in conglomerates within the unit and represent reworked material. Therefore, only the maximum age of the localities is significant. The conglomerates could represent a later stage than the fossil age but not earlier. The fossils and the stages that they represent are listed in the appendix (L. Saul, written communication, 1967).

Fossil locality UCB-761 occurs a few hundred feet below the top of unit II. According to LouElla Saul the fossils are characteristic of the Santonian Stage. Fossil localities UCB-765 and 766 occur in unit II, directly above the contact with unit I, the Adobe Flat Shale Member of the Panoche Formation (Maddock, 1964). These two localities appear to be at or very near the same stratigraphic horizon. Therefore, these lower beds of unit II can be no older than the Coniacian Stage.

Conglomerates which unconformably overlie the unit contain Campanian fossils (discussed below), and the underlying Adobe Flat Shale Member contains Turonian fossils. Anderson (1958, p. 31) reports the occurrence of *Peroniceras quintoense* n. sp. (locality C.A.S. 29596) from Shales directly above the uppermost conglomerate bed in the Panoche Formation along Quinto Creek. Matsumoto (1960, p. 51 and 88) refers this locality to the Coniacian Stage. This conglomerate and overlying shale appear on the basis of regional mapping and stratigraphic position to be equivalent to unit II along Del Puerto Creek. It therefore seems probable that unit II represents the Coniacian and the Santonian Stages but may range from upper Turonian into the lower Campanian.

The above correlation between beds exposed at both Del Puerto Creek and Quinto Creek means that the Adobe Flat Shale Member represents the Pacheco Group, and unit II the basal beds of the Asuncion Group (Taliaferro, 1943, p. 130–132).

UNIT III

Unit III, which consists principally of conglomerate and sandstone with minor amounts of brown shale, unconformably overlies the brown shales of unit II. In the canyon of Del Puerto Creek unit III is about

1500 feet thick. The size of the clasts is gradational from the bottom to the top of the unit. Coarse conglomerate with boulders as large as a foot or two in diameter occurs near the base. The central portion is composed of pebbles generally two or three inches in diameter, and the top is marked by a pea-sized gravel overlain by gritty sandstone which grades upward into fine- to coarse-grained sandstone. The most common pebbles in the conglomerate are feldspar porphyry; red, green, and black chert; vein quartz, quartzite, and metavolcanic rocks. Also present are angular blocks of soft shale a foot or two long, pebbles of hard shale and sandstone (some of which were found to contain *Inoceramus* fragments), and occasional clasts of granitic rock. the sandstones above the conglomerate are arkosic and contain abundant carbonaceous material and common shale fragments. The matrix of the conglomerate is an ill-sorted mixture of sand and clay. The sandstones are also ill-sorted, silty and clayey. The conglomerate includes a six- to eight-foot interbed of brown, thinly bedded claystone about 200 feet above the base.

Graded bedding can be seen in many of the individual conglomerate beds; however the grading is seldom complete. Channeling is common, but the writer was unable to find any indication of cross-bedding. A few examples of imbrication of the pebbles were noted; in each case the current direction indicated was from west to east (fig. 4).

This conglomerate can be traced for about one mile and a quarter southward from Del Puerto Creek, where the conglomerate and the lower 100 feet of the overlying sandstone end abruptly in a buttressing relationship against shale of the underlying unit. About a mile to the north of Del Puerto Creek they disappear as a result of buttressing against the underlying unit and overlap of the overlying sandstone.

As no evidence of faulting could be found, these relationships indicate that the conglomerate and part of the overlying sandstone represent sediments deposited in a topographic low or submarine channel eroded in the sea floor or on the slope of the margin of the basin. This relationship is discussed more fully in the section on structure.

Anderson (1958, p. 41) reports the following fossils from locality C.A.S. 28323, which is in the SW ¼ of Section 35, T.5 S., R. 6 E. (this location is either within or directly below the conglomerate of unit III near Del Puerto Creek):

Canadoceras aff. *C. Multicostatum* Whiteaves
Baculites inornatus Meek
Pseudomelania colusaensis n. sp., *Inoceramus* aff. *I. pembertoni* Waring
Anchura falciformis (Gabb)
Inoceramus cf. *I. undulatoplicatus* Roemer

Anderson assigned a Coniacian age to the locality, but Matsumoto (1960, p. 177 and Pl. I) and Popenoe *et al.* (1960, chart 10e) consider *Baculites inornatus* Meek to be Campanian. On the basis of the foregoing the writer considers the unit to be Campanian in age.

Figure 5. Photo of Cancretionary Sandstone Beds in Unit V. The beds, a few feet thick, accur in groups (sometimes referred ta as "bundles") that stand aut as resistant pramantories an the skyline, separated by less resistant siltstones and claystanes.

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UNIT IV

Unit IV lies conformably above the conglomerates and sandstones of unit III and is composed of 2450 feet of thin-bedded, fine-grained, silty, clayey sandstones, siltstones and claystones. The fine-grained sandstones and the siltstones have sharp bottom contacts and grade upward into claystones. Laminations occur near the top of the sandstone and siltstone beds, and convolute bedding is common. The unit as a whole is relatively non-resistant to weathering, and good exposures are rare except along part of the course of Del Puerto Creek.

Sandstone becomes more prevalent in the upper few hundred feet of unit IV, and individual beds as much as several feet in thickness are exposed. Load waves and pockets are common at the base of these thicker sands. The orientation of the casts is generally east-west, but the sense of direction of the current was not determined.

The contact of unit IV with the overlying unit V along Del Puerto Creek and for at least five miles to the south appears to be conformable, but northwest of Del Puerto Creek the strike of the beds in unit IV changes from northwest to north and the dip steepens to nearly vertical. The attitude of the overlying unit V beds does not change, and consequently the lower beds of unit V buttress against the underlying beds of unit IV. The contact thus is an angular unconformity. This relationship and its effect on the interpretation of the stratigraphy is discussed in more detail in the later section on structure.

At fossil locality UCB 759, located directly southwest of the north quarter corner of Section 26, T.5 S., R.6 E., Maddock (1955, pl. 4) reports *Baculites* cf. *B. chicoensis* Trask. This locality is near the middle of unit IV. *Baculites chicoensis* is characteristic of the lower part of the Campanian according to Popenoe *et al.* (1960, Chart 10E).

UNIT V

Unit V is composed of 3500 feet of alternating shale and concretionary sandstones. The sandstones are fine-grained, arkosic, silty to clayey, and grade upward into carbonaceous siltstones and claystones. Calcareous

Figure 6. Photo of Flute Casts on Base of Sandstone Bed. The flute casts, near middle of unit V along Del Puerto Creek, indicate current direction from right to left (southeast to northwest).

Figure 7. Photo of Outcrops of Unit VI Sandstones Along Del Puerto Creek. This unit is characterized by the absence of any appreciable amount of shale.

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concretions from an inch or two to a foot or more in diameter are common in the sandstones. The sandstones are most commonly in beds a foot to three feet in thickness and occur in groups generally totalling fifty to several hundred feet. These groups or "bundles" are separated by one- to three-foot intervals containing thin beds of claystone and siltstones (fig. 5).

Sedimentary structures typical of turbidites such as load casts, load pockets, and load waves, are common in the sandstones. These structures are aligned in a northwest-southeast direction, parallel to the strike. Sole markings other than load casts are rare. Flute casts on the bottom of one bed indicated a southeast to northwest (N45°W) current direction (fig. 6). Cross laminations in another bed near this same horizon also indicated current flow from the southeast.

Both to the north and south the upper contact rises stratigraphically. Along Hospital Creek at DMG locality 3 *Baculites inornatus* Meek and *Metaplacenticeras* cf. *M. pacificum* (Smith), characteristic of the Campanian Stage (Popenoe *et al.*, 1960, chart 10e), occur in a thin conglomerate bed near the top of the unit. Here the top of unit V is about one thousand feet higher stratigraphically than along Del Puerto Canyon. Between Ingram and Hospital Creeks the lower sandstones pinch out, and the lowermost shales buttress against faults, which bring either the Franciscan Formation or the Adobe Flat Shale Member into juxtaposition with these beds.

The thick bodies of shale in unit V represent fine-grained material (silt and clay) of pelagic origin, which required relatively long periods of geologic time to accumulate. Periodically, probably because of uplift in the source areas, turbidity currents deposited sand in "bundles" 50 to several hundred feet thick. These now form resistant, brush-covered outcrops of concretionary sandstone. In a geologic time sense these turbidite sequences were instantaneous. This concept helps to explain how such great thicknesses of rocks could be deposited in this area during the relatively short period of time represented by a small part of the Upper Cretaceous. Along Del Puerto Creek the Campanian Stage of the Upper Cretaceous is represented by at least 15,000 feet of sedimentary rocks.

UNIT VI

Above the interbedded concretionary sandstone and shale of unit V are about 4000 feet of fine-grained, silty to clayey, arkosic, concretionary sandstones which are referred to as unit VI. These sandstones occur in beds two to ten feet thick. The unit is characterized by the absence of any appreciable amounts of shale (fig. 7). With the exception of a few three- to four-foot claystone beds near the base, about 90 percent of the unit is composed of sandstone. Many of the beds grade upward to a fine-grained, silty, laminated, layer, with thin claystone comprising their tops. Flame structures, load casts, waves, pockets, and small-

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Figure 8. Photo of Sedimentary Features in Unit VI. The flame structures, channeling, graded bedding and other sedimentary features associated with deposition from turbidity currents are exposed in outcrops of unit VI along Del Puerto Creek.

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scale slump structures are common (fig. 8). Along Del Puerto and Salado Creeks the load waves and casts indicative of the direction of current flow are aligned northwest-southeast. Two instances of cross lamination, one along Salado Creek and the other along Del Puerto Creek, indicate a southeast to northwest current flow. Along Ingram Creek the alignment of the load features is in a northeast-southwest direction but along Hospital Creek the alignment is nearly east-west. No indication of the sense of direction was obtained in either of these latter two areas.

UNIT VII

Unit VII is the uppermost unit of the Panoche Formation and consists of thickly bedded to massive sandstones with thinner interbeds of claystone and siltstone, particularly in the lower half. The sandstones are light gray, fine- to medium-grained. They are arkosic, composed principally of feldspar, quartz and biotite in a silty to clayey matrix. The coarser grains are commonly rock fragments—principally green chert and gray quartzite. The sandstones occur in beds from a few inches to several feet in thickness. Near the base, the sandstones appear very massive, but close examination shows that they are in beds three to four feet in thickness separated by very thin beds or laminae of silt or clay. Carbonaceous material is abundant in the upper parts of many of the beds. Shale fragments are also common (fig. 9). Graded bedding is not obvious because of the fine-grained nature of the sandstones. However, coarse grains are found in pockets or channels at the base of the sandstone beds, and the tops of many of the thinner beds are characterized by a zone of laminated silt. Often there is a thin layer of pelagic clay overlying the sand and silt.

The axes of sedimentary structures are strongly aligned in a northwest to southeast direction (figs. 10 and 11). A northwest to southeast sense of current direction was obtained from cross stratification observed in outcrops along Del Puerto Creek. This same directional sense was inferred from the overfolding of mudstone similar to that illustrated by Crowell and others (1966, figure 17B, p. 27). Observations of the sense of current direction were limited to one or two good outcrops and were too few to give conclusions that would be statistically meaningful.

Unit VII disappears southward in the vicinity of Crow Creek. The pinch-out of the unit is accomplished in several abrupt and distinct stages as indicated on plate 1. Several hundred feet of sandstones disappear within a few hundred yards along strike. A mile or so north of Del Puerto Creek the shales in the lower part of the unit are missing and the lower contact is not traceable. South of Martin Creek a sand lens within the Moreno Formation merges with the top of the Panoche a short distance to the north (pl. 1).

Along Hospital Creek unit VII is characterized by a sand-on-sand relationship, and sedimentary structures which usually occur in the shaley upper portions of

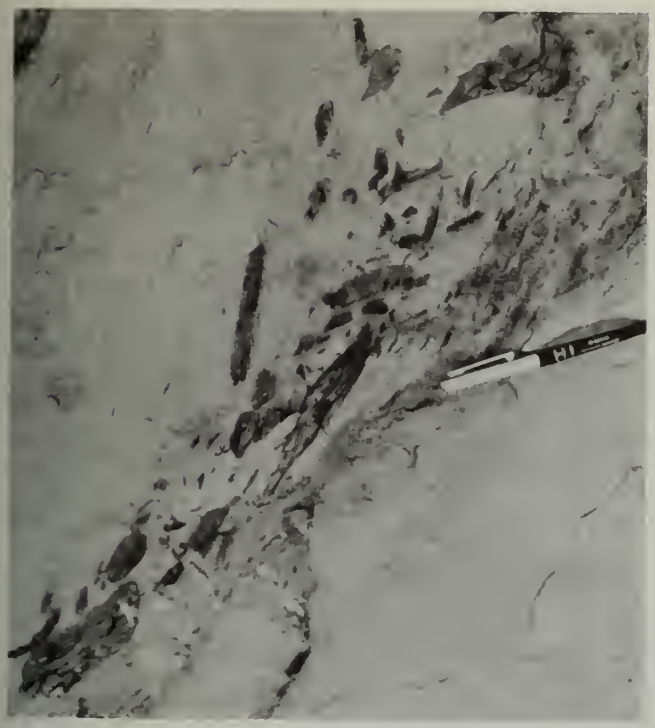

Figure 9. Photo of Small Fragments of Shale in Unit VII. The curved nature of some of the fragments, in the upper portions of sandstone beds, attests to the plastic nature of the material at the time of deposition. *Photo by T. H. Rogers.*

Figure 10. Photo Facing Southeast Along the Strike of Unit VII. The plane of the outcrop is normal to the southeast-northwest alignment of the axes of the load pockets and load waves.

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turbidite beds are generally missing. This is interpreted as indicating the currents were stronger and eroded the tops of the underlying beds prior to depositing their load. Here, the sands are much coarser grained than to the south, indicating deposition was closer to the source. The southeastward lensing out of the sands and the northward coarsening of grain size and suggestion of stronger current flow, together with the sedimentary structures observed, strongly suggest that the depositing currents moved from northwest to southeast.

Samples from shales 750 feet below the top of unit VII along Del Puerto Creek (DP-302) and 1600 feet below the top of the unit along Hospital Creek (HOS-113) both contained the Goudkoff E zone marker *Planulina constricta*. Charles W. Cary (oral communication, 1964) reports having obtained this Foraminifera from a shale bed along Ingram Creek located about 610 feet below the top of the Panoche. Popenoe *et al.* (1960, chart 10e) correlate the E zone of Goudkoff with the Campanian Stage.

Moreno Formation

The Moreno Formation lies conformably above the Panoche Formation and, as used in this report, is the same as originally mapped by Anderson and Pack (1915, pl. 1). It is composed of dark gray to dark brown shale that characteristically weathers to a chocolate brown color with a purplish cast, and light to dark gray sandstone that weathers to buff brown. The shale is thinly bedded, often silty and contains small fragments of carbonized wood. Selenite is commonly developed along fractures and bedding planes. Fossil material is locally abundant and includes shells of ammonites and pelecypods, foraminifera tests, dinosaur bones, *Inoceramus* prisms, fish scales, bones and teeth, and a rich flora of pollens, spores and algae. The shale is very similar in appearance to shale that occurs in the upper part of the Panoche Formation, but its greater thickness and abundant fossil content indicate that the shale of the Moreno was deposited in a different environment from that of the Panoche.

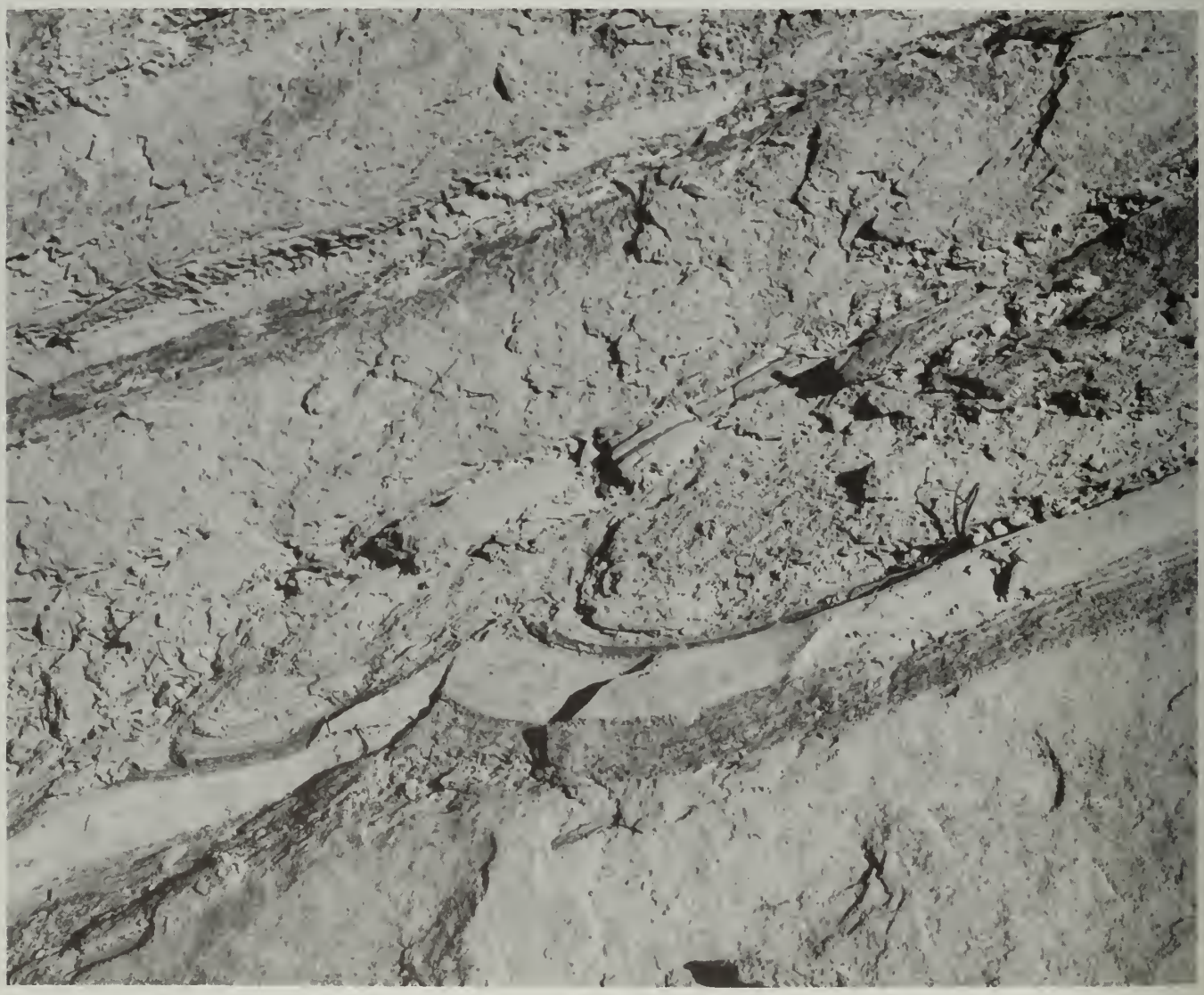

Figure 11. Photo Facing East Showing Assymetrical Nature of Sedimentary Structures. The structures appear assymetrical when viewed at an oblique angle to the northwest-southeast alignment of their axes.

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Figure 12. Photo of Sandstones Within the Moreno Formation. The sandstones attain thicknesses in excess of 500 feet near Del Puerto Creek. The sandstone unit shown belongs to Goudkoff's D-1 zone and is lithologically and biostratigraphically correlative with the "Blewett sand," which produces gas at the Vernalis field in the San Joaquin Valley a few miles to the northeast.

Several sandstone units, which range in thickness from about 175 feet to over 500 feet, are present within the Moreno and are particularly well exposed in the Del Puerto Creek area and southward (pl. 1 and fig. 12). The lower sandstone beds thin rapidly to the northwest, and the upper beds—the Garzas Member in this report—are truncated by Tertiary rocks between Del Puerto and Ingram Creeks. Along Ingram and Hospital Creeks only sandstone beds a few feet in thickness occur in the shale of the Moreno Formation.

Along Del Puerto Creek the individual sandstone beds are generally a foot or two thick near the top of the Moreno but are thicker and more massive near the base. They are light gray, weathering to buff or brown, firm but generally friable, fine- to medium-grained with occasional coarse grains, ill-sorted, silty and clayey. Calcite is a common cementing material, and the beds contain numerous calcareous and ferruginous concretions which range in diameter from less than an inch to several feet. As is characteristic of the Upper Cretaceous sandstones, they are arkosic and are composed principally of feldspar, quartz, wrinkled biotite (commonly altered), and rock grains—mostly chert and quartzite. Potash feldspar commonly accounts for about 25 percent of the total feldspar, and 5 to 10 percent of this is microcline.

Sedimentary structures occur in the sandstones in the upper half of the formation. These structures include load waves and load pockets, load casts, flute casts, groove casts, and cross laminations. The beds are crudely graded but the grading is rarely complete. Large, well-rounded masses of shale one to two feet in diameter occur in the thicker sandstones, and small to large angular fragments of shale are present in the Garzas Member. Fairly large scale slump structures were observed in the north bank of Del Puerto Creek near the base of the Garzas Member (fig. 13).

These features, together with the dirty, silty nature of the sandstones and lack of large scale cross-bedding or ripple marks, indicate that most of the sandstones of the Moreno Formation along Del Puerto Creek were deposited by density or turbidity currents. Directional features are not common and too few were observed for statistical determination of the paleocurrents direction. Cross-laminations and one flute cast near the middle of the formation indicated a southeast to northwest current flow. The slump structures near the base of the Garzas Member are interpreted to indicate that the slumping and the downward slope of the floor of the basin was from west to east.

GARZAS MEMBER

Reference to the Garzas has been made in different ways by different authors, and even in different ways by the same author at different times. Garzas beds, Garzas sand, Garzas sandstone, Garzas Member, Garzas Formation, and Garzas Stage all appear in the literature (Huey, 1937, p. 335; Anderson, F.M., 1937, p. 1612; Anderson, F.M., 1940, p. 395; Camp, 1942; Anderson, F.M., 1943, p. 185, 186; Taliaferro, 1943, p. 132; Stewart and others, 1944; Goudkoff, 1945, p. 979–980; Briggs, 1953a, p. 421; Anderson, F.M., 1958, p. 59–60).

Regardless of the modifier associated with the name, the term Garzas is consistently referred to the uppermost Cretaceous sandstones that crop out along the western side of the northern San Joaquin Valley north of Pacheco Pass. Anderson and Pack (1915, p. 56) describe an upper sandstone unit in the Moreno

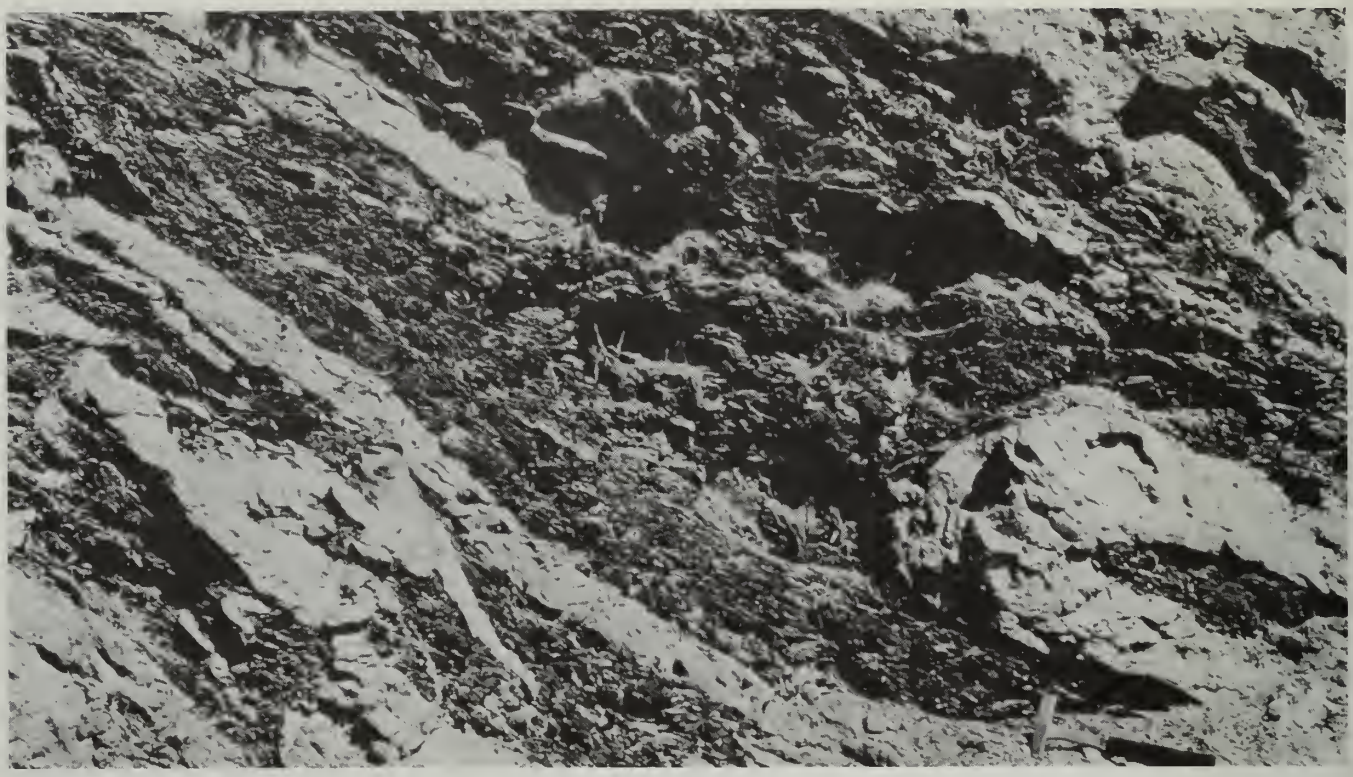


Figure 13. Photo of Slump Structures Within the Garzas Member. The Moreno Formation structures occur in the outcrop along Del Puerto Creek. *Photo by T. H. Rogers.*

Formation which they mapped (1915, Pl. I) from Quinto Creek to Del Puerto Creek. F.M. Anderson (1958, p. 59–60) correlates this sandstone member with the Garzas sandstone described by Bennison (1940, unpublished). It is in this latter manner that the Garzas Member of the Moreno Formation is used in this report.

The Garzas Member is much finer grained and thicker along Del Puerto Creek than in the Quinto-Garzas Creek area, where it is commonly conglomeratic and contains a rich megafossil fauna. Along Del Puerto Creek the unit is 1,461 feet thick (Pl. II) and is composed of an upper and a lower sandstone separated by about 700 feet of brown claystone. The claystone in the Garzas Member is similar in appearance and lithology to other claystones in the Moreno Formation. The upper sandstone unit is medium-grained, arkosic, silty and clayey, and contains common to very abundant carbonaceous material, which commonly gives a dark gray color to the sandstones. The unit occurs in beds from a few inches to two feet thick, interbedded with medium to dark gray sandy siltstone. The beds are graded upward and exhibit sedimentary structures such as load pockets and load waves typical of turbidity current origin. The lower sandstones are similar to the upper ones but are somewhat coarser grained and occur in beds 10 to 15 feet in thickness. Carbonaceous siltstone beds are common, and carbonaceous material, shale fragments and occasional small pebbles occur in the sandstones.

The change in character of the Garzas Member from south to north suggests that it was deposited in a near-shore shallow water environment in the Quinto-Garzas Creek area and that to the north the shore was more distant and the water deeper.

A Campanian and Maestrichtian age appears well-established from the fossil evidence for the Moreno Formation in this area. Matsumoto (1960, p. 53–55) has reported on the Cretaceous ammonite localities in the Orestimba and Carbona quadrangles. Several of these localities occur within the Moreno Formation as herein used. CAS. 29664, located in the NE ¼ of the NE ¼ of Section 30, T.5 S., R.7 E. in the Moreno Formation on the north side of Del Puerto Creek, contains, according to Matsumoto (1960, p. 89), the following: *Pachydiscus* cf. *P. ootacodensis* (Stoliczka), *Didymoceras* cf. *D. hornbyense* (Whiteaves) and *D.* cf. *D. vancouverense* (Gabb). To these Matsumoto has assigned a Campanian age. At or near this locality *Acila* shells and external molds of *Inoceramus* shells are common in the shales that form a dip slope above a large landslide. Bones from a duck-billed dinosaur (Hesse and Welles, 1935), the first dinosaur remains reported from the Pacific Coast, were found by Bennison in the slide material directly below this locality. Bennison (oral communication, 1965) obtained *Acila demessa* Finlay from this same stratigraphic unit directly to the south of Del Puerto Creek. *Acila demessa* ranges from Coniacian to Campanian, according to Popenoe *et al.* (1960). From locality CAS. 19666 on the south side of Del Puerto Creek, in the center of the SW ¼ of Section 29, T.5 S., R.7 E., Matsumoto (1960, p. 89) reports *Didymoceras vancouverense* (Gabb) and gives a late Campanian or earliest Mae-

strichtian(?) age to the locality. This locality appears to be close to the stratigraphic position of CAS. 29664, mentioned above. Matsumoto (1960, p. 88, 89) reports on two localities near Little Salado Creek. Locality CAS. 29671 is near the base of the Moreno and is Campanian or lower Maestrichtian, whereas locality CAS. 29652, at least several hundred feet stratigraphically higher and near the base of the Garzas Member, is lower Maestrichtian.

Foraminifera belonging to Goudkoff's D-1, D-2, and E zones occur in the shales of the Moreno Formation along Hospital and Ingram Creeks, and C and/or D-1, D-2, and E zone species have been collected along Del Puerto and Salado Creeks. Diagnostic localities have been indicated on the columnar sections, and a fossil list is presented in the appendix. Hacker (1950) reports Foraminifera of the C and/or D-1 zones from the Garzas Member along Del Puerto Creek.

SUBSURFACE PROJECTION OF THE MORENO FORMATION

The lithologic and biostratigraphic equivalents of the Moreno and upper parts of the Panoche Formations occur to the east beneath the younger sedimentary rocks of the northern San Joaquin Valley. Logs of wells drilled in the search for oil and gas give a three-dimensional picture of the stratigraphy of this part of the stratigraphic column. A subsurface nomenclature has been built up by the petroleum industry, and it is one of the purposes of this paper to relate this nomenclature to the rocks that crop out on the surface in this area.

The subsurface terms used by the petroleum industry were described in papers by Hoffman (1964), Callaway (1964), and Teitsworth (1964). Figure 14 section A-A′ (after Hoffman, 1964, fig. 5, p. 39) is a regional stratigraphic section, drawn eastward from the Shell Oil Company Elfers 36X-28 well, located in Section 28, T.5 S., R.7 E., a mile south of Del Puerto Creek, to the vicinity of Atwater on the eastern side of the San Joaquin Valley (see fig. 1).

The Shell well spudded in the Moreno Formation and penetrated sandstones and shales of this formation and the upper part of the Panoche Formation. Figure 15 shows the correlation of the electric log of this well with the measured section of the outcrop along Del Puerto Creek. Supporting paleontological data is shown on the margins. The upper sandstone between 760 and 800 on the electric log is present in the outcrop to the west of the well but pinches out before reaching Del Puerto Creek.

Figure 14 shows the thickening of the "Blewett" and Garzas sandstones interval in an eastward direction. Isopach maps (Hoffman, 1964, figs. 7, 9 and 10, p. 41–44) indicate that the axes of the basins of deposition during the Late Cretaceous were to the east of the present outcrops, beneath the younger sedimentary rocks of the San Joaquin Valley.

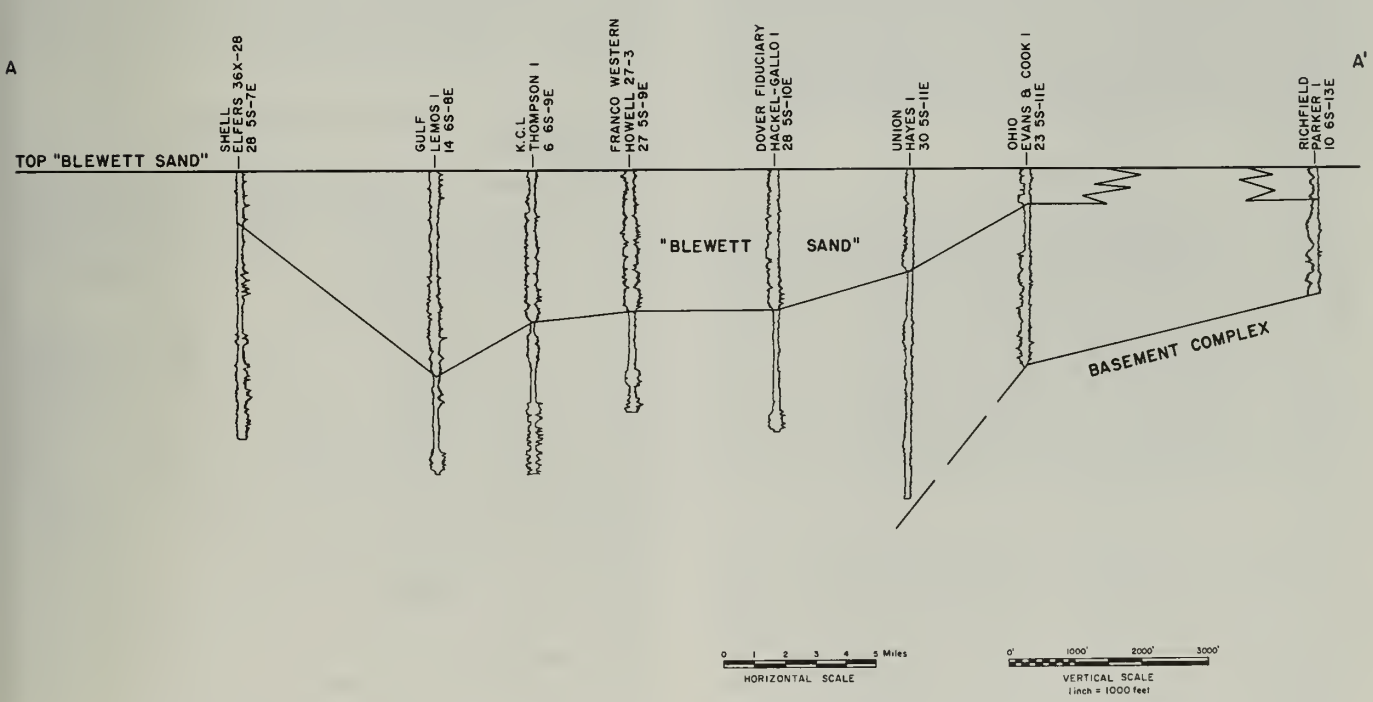


Figure 14. East-West Subsurface Stratigraphic Section. The line of Section runs from the vicinity of Del Puerto Creek on the west to the town of Atwater on the east side of the San Joaquin Valley. *After Hoffman, 1964, fig. 5, p. 39.*

ENVIRONMENT OF DEPOSITION

A near shore and shallow water environment is suggested in the outcrops of the Moreno Formation along the west side of the northern San Joaquin Valley by the relative abundance of megafossils. These include oyster shells and dinosaur remains, mosasaurs (Camp, 1942), pholas-bored zones (Taliaferro, 1943, p. 132), and fresh water algae, pollens and spores from phosphatic nodules (Evitt, oral communication, 1966). Turbidites, although commonly associated with deep water, may also accumulate in shallow water, and their sedimentary structures may be preserved if they are deposited below wave base. If a protective land mass exists between the depositional area and the open ocean the wave base may be quite shallow. The areal extent of the Moreno Formation and its time-stratigraphic equivalents shows that the Upper Cretaceous sea extended for many miles both north and south of the area of this report along the eastern flank of the Diablo Range. Cross-section A-A′ (fig. 14) and the isopach maps mentioned above clearly show the thickening of these marine sedimentary rocks to the east. Therefore the land area must have been to the west, in the area now occupied by parts of the Diablo Range.

STRUCTURE

The predominant structural feature of the Upper Cretaceous rocks along the west side of the San Joaquin Valley is a homocline of steeply east-dipping beds. Dips are generally between 50 to 65 degrees but locally the beds become vertical or overturned to the west. The Salado anticline, an asymmetrical structure with a steep east limb and a gentle west flank, is an exception. This north-south trending structure occurs in the outcrop of the Moreno Formation and plunges southward between Del Puerto and Salado Creeks. Other, more subtle, structural features that are important to the understanding of the stratigraphy will be discussed following a brief review of the faulting in this area.

Faults

The Tesla-Ortigalita fault (Maddock, 1964) generally is the boundary between the upthrown, sheared and complexly folded rocks of the Franciscan Formation on the west and the younger Mesozoic sedimentary rocks on the east. Although generally considered as one fault it appears to be a more complex fault system. Occasionally the faults associated with this system extend into the Cretaceous sedimentary rocks and in other places the faults appear to be wholly within the rocks of the Franciscan Formation. Both of these features can be seen in the vicinity of Hospital Creek.

Cross-faults (normal to the strike of bedding) were observed in rare instances. The Panoche-Moreno contact is offset just south of Hospital Creek, near the San Joaquin-Stanislaus County line. The stratigraphic separation of this offset is about 1100 feet and is believed to be caused by a steeply dipping, north-trending fault. Another north-trending fault but with much smaller displacement extends southerly through Section 30, T. 4 S., R. 6 E., about one mile southwest of the above mentioned displacement. Minor faults with displacements of only a few feet were observed in the outcrop along Hospital Creek.

Unconformities—Interplay Between Tectonics and Stratigraphy

GENERAL

In studying the lithology and stratigraphy of the Upper Cretaceous section it is readily apparent that in any one stratigraphic sequence distinct groups of rocks are lithologically similar. It is also true that these groups significantly differ from each other. This suggests that the environment in the area of deposition was stable over fairly long periods but that these conditions were interrupted locally from time to time by tectonic events. These events resulted in the periodic deepening of the basins of deposition and/or shifts in their axes. These effects probably were associated with uplift in the source areas and the creation of new source areas.

Although tectonic activity probably resulted in the formation of angular unconformities along the margins of the basins, the downwarping or deepening in the major parts of the basins took place without any appreciable angular discordance between the strata. The outcrop areas of most of the Panoche Formation represent the rocks that were deposited in the deeper parts of basins. Only in rare instances are interruptions in deposition associated with angular unconformities that can be recognized in the sedimentary column.

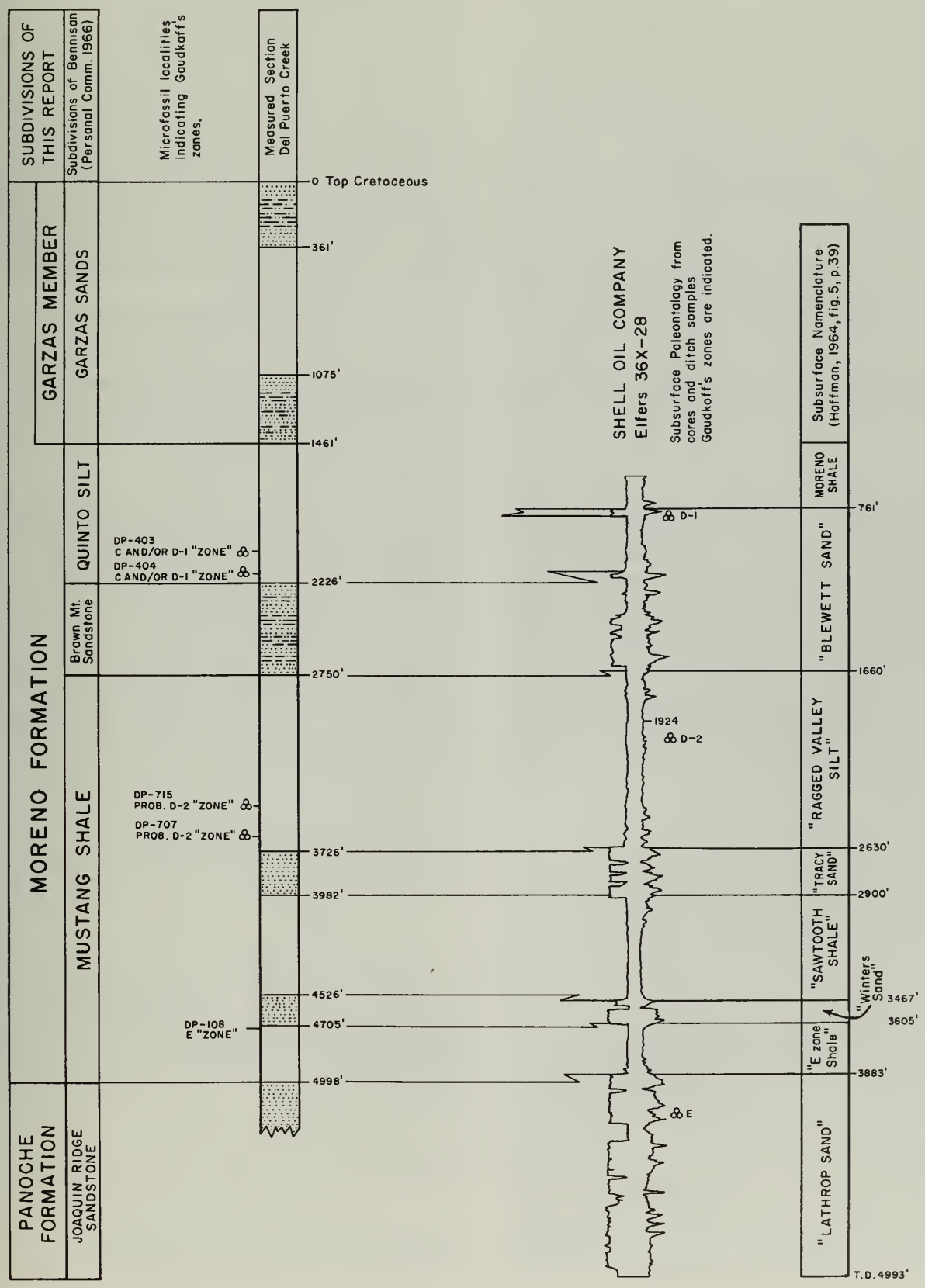
In the study of the Upper Cretaceous rocks of this area it is very important to recognize the numerous gaps in deposition wherever they exist. In the absence of clear evidence for tectonic activity, observed lateral changes in lithology may be erroneously attributed to changes of sedimentary facies.

EXAMPLES OF TECTONIC-STRATIGRAPHIC RELATIONSHIPS

Three instances of tectonic movements that affected deposition were recognized during this investigation and are discussed below. Probably other tectonic events occurred during the depositional history but they have not been identified.

A). The conglomerates of unit III that crop out in the SW ¼ of Section 35, T. 5 S., R. 6 E. thin rapidly and disappear about one mile north of Del Puerto Creek. In the outcrops, along the course of the creek, the basal beds of the conglomerate buttress on the south against thin-bedded shale and siltstone of the underlying unit II (see fig. 16). Here, the difference in strike and dip between strata of units II and III is sufficient to demonstrate an angular unconformity between them. The upper part of the conglomerate extends south of Del Puerto Creek for about a mile where it ends abruptly also, buttressing against shale in the north half of Section 2, T. 6 S., R. 6 E. In this area the attitudes in the conglomerate are very similar to those in the underlying beds, and the contact is interpreted as a disconformity. Without the particularly good exposures at the critical location along Del

Figure 15. Correlation of the Measured Section Along Del Puerto Creek With the Shell Oil Company Elfers 36X-28 Well. The correlation shows the relationship of the subsurface nomenclature to the surface exposures.



Puerto Creek, the hiatus between the two units could easily be overlooked, and the relationship might erroneously be interpreted either as a facies change within a single conformable unit, or as a fault-caused buttressing of the conglomerate. The following interpretation is offered as an explanation of the observed data.

Following the deposition of the sandstone and shale of unit II, uplift of the region to the west and the western part of the basin created an easterly dipping submarine slope and warped the basin floor to create a submarine topographic low in the area of Del Puerto Creek. Sediments carried eastward down the slope by turbidity currents eroded a channel in the basin floor. Subsequently, the channel and topographically low area were filled and buried with coarse clastic material.

B). Evidence of another tectonic event is at the base of the concretionary sandstone and shale of unit V in the southwest quarter of Section 26, T. 5 S., R. 6 E. along Del Puerto Creek. Unit V is approximately 3500 feet thick in the canyon of Del Puerto Creek but is about half this thick in Kern Canyon, three miles to the north. The thinning is not a result of erosion of the top of the unit because the uppermost shale bed has been mapped intact from Del Puerto Creek northward beyond Kern Canyon. Throughout most of the outcrop area examined, unit V appears to be conformable with the underlying unit IV. However, northwest of Del Puerto Creek, in the west half of Section 22 and the NW ¼ of Section 27, T. 5 S., R. 6 E. the underlying beds change in strike, and their eastward dip steepens. The lower concretionary sandstone beds of unit V buttress against this contact (fig. 17). Warping of the basin floor and uplift to the west, probably associated with a deepening of the depositional basin, followed the deposition of unit IV and caused an unconformity between the two units. At the time of deposition the north part of the basin floor near Kern Canyon and northward was topographically higher than the south part. The sandstones of unit V were deposited by turbidity currents probably coming from the south. The lower sandstones were deposited in the topographically low area near Del Puerto Creek and southward. After this depression was filled the turbidity currents spread northward and deposited their load over the entire area. Most of the shale beds of unit V are of pelagic origin and so were deposited more or less evenly over the entire basin, regardless of minor differences in topographic relief. Thus the northward thinning of unit V is the result of non-deposition of the coarser basal sandstone members in that area.

Other more subtle unconformities within the rocks studied were inferred from the mapping but angular relationships of the beds could not be proven. In part this is because the very minor variations in the dip and strike of beds above and below these contacts are of smaller magnitude than the local variations in the attitudes of individual beds.

In areas where the formations are less well exposed or where the change in attitude of the beds of adjacent units is slight, the unconformable relationships could easily go unnoticed. The thinning might then be erroneously interpreted as a northward facies change in which the lowermost concretionary sandstones of unit V grade laterally into the thinner bedded sandstones and shales of unit IV.

C). Similar larger scale structural-stratigraphic relationships probably occur many times during the depositional history of any geosyncline. Periodically during the Late Cretaceous, folding and faulting shifted the axis of deposition from west to east. During these periods of tectonic activity probably several contemporaneous depositional basins existed within the broad province of the Cretaceous geosyncline.

Evidence of the formation and subsequent filling of one of these basins can be studied in the Moreno Formation of this area. The thickening of the "Blewett sand" from about 550 feet on the west to more than

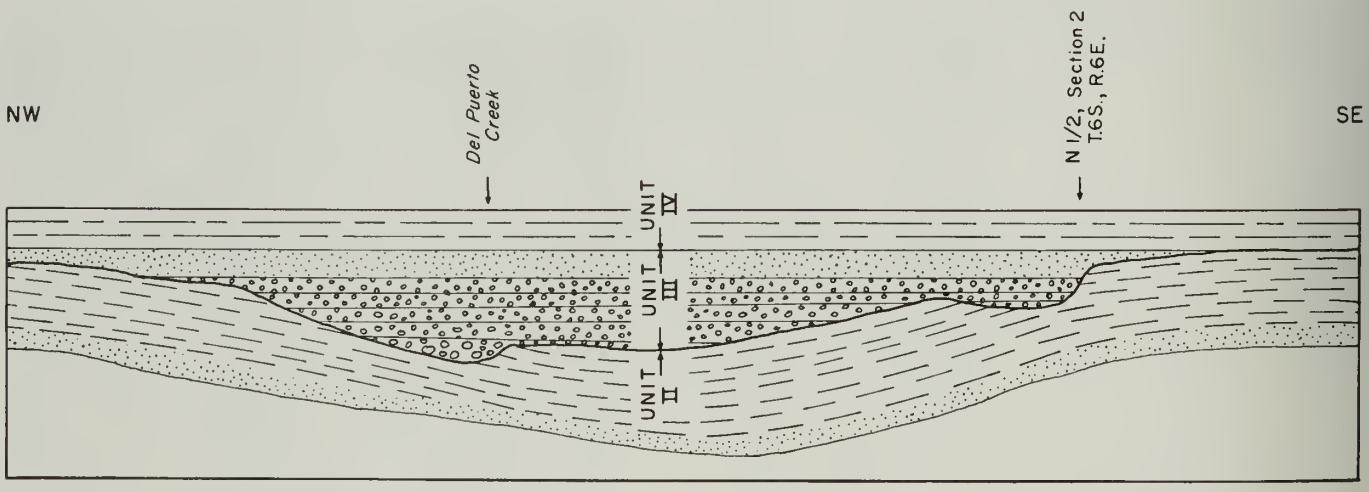


Figure 16. Cross-Section Through Conglomerate Lens in the Del Puerto Creek Area. The section is diagrammatic, northwest to southeast.

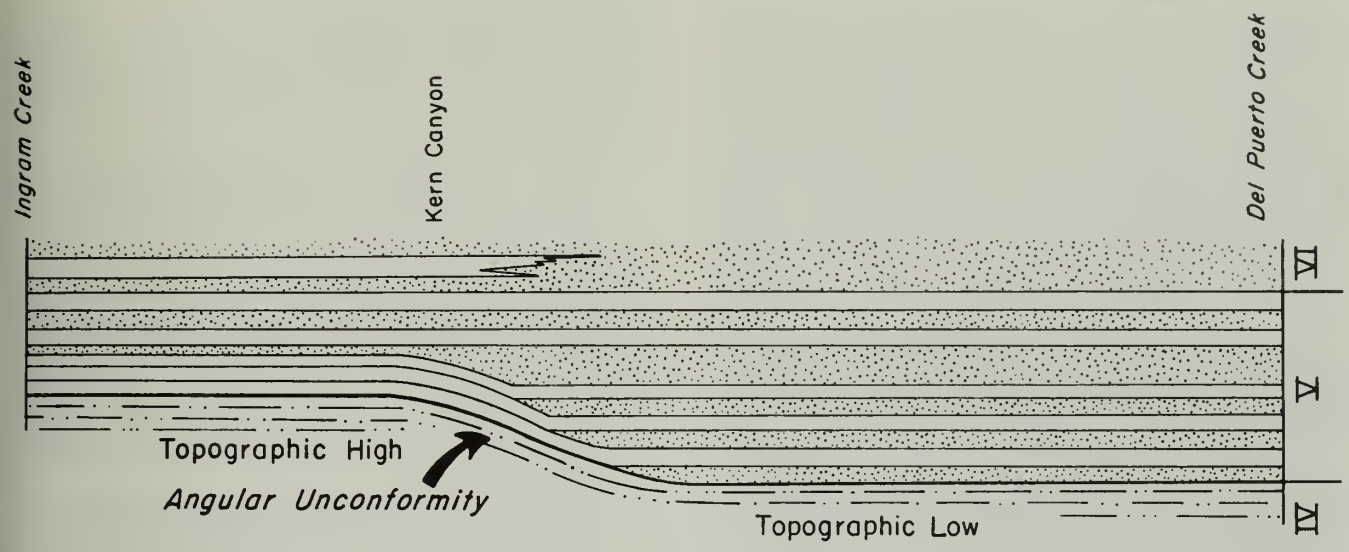


Figure 17. Cross-Section Between Del Puerto Creek and Ingram Creek. The north-south diagrammatic section shows the relationship between the structural warping of the basin floor, following the deposition of of Unit IV, and the resulting stratigraphic variations within unit V.

2,000 feet in the central part of the basin is readily apparent on the cross section, figure 14. Correlations by the writer of electric logs in this area indicate that the eastward thickening of the "Blewett sand" is caused by the addition of sandstone beds at the base of the formation. Sands at the top can be correlated from well to well for some distance whereas the lower sands appear to buttress against the underlying shale. These relationships are analogous to the foregoing example. After the deposition of the "Ragged Valley silt", folding and possibly faulting created a topographic depression in the area now occupied by part of the northern San Joaquin Valley. Subsequently the deeper parts of the basin received sediments, principally sand, carried by turbidity currents. After these deeper parts were filled, the currents flowed across them to the shallower areas beyond and deposited some of the sands that crop out along the west side of the valley.

ECONOMIC AND PALEOGEOGRAPHIC IMPLICATIONS

The mechanism described consists of basin formation and subsequent filling by a thousand feet or more of sediment prior to any appreciable large-scale downwarping or realignment of depositional axis. This mechanism results in a somewhat different stratigraphic and structural relationship than would be the case if downwarping were slow and more or less continuous during deposition. One of the principal effects is the creation of a buttress and overlap zone along the steeper parts of the paleo-basin floor, which could well contain numerous stratigraphic traps favorable to the accumulation of oil and gas.

It appears that during late Cretaceous time, basins or topographic depressions probably several thousand feet deep were periodically formed. Following the formation of such a basin, sedimentation would continue under fairly stable tectonic conditions, filling to varying degrees and flattening the sea floor in these depressed areas. Then renewed diastrophism would again modify the submarine topography of the region. The axis and locations of these basins varied, but the net result was a shifting of the depositional area from west to east—and a transgression of the late Cretaceous seas onto the land mass ancestral to the Sierra Nevada.

Because of the probable coexistence of two or more basins (or sub-basins) of deposition at various times during the late Cretaceous, as well as the possibility of multiple sources of sediment, great care need be taken in the regional correlation of rock units. Unless a unit can be physically traced to the type area, it may be erroneously concluded that lithologically similar rock sub-divisions of similar age represent a single unit, whereas, they may be contemporaneous but non-contiguous units. Partly for this reason, the writer hesitates to extend the nomenclature of the subdivisions of the Panoche Group in the Panoche Hills (Payne, 1962) to the area north of Pacheco Pass.

SOURCES OF SEDIMENTS

The location of the source area for the Upper Cretaceous sedimentary rocks has been a matter of argument and controversy for many years. The rock in the source area surely was primarily granitic as evidenced by the arkosic nature of the sandstones. A volcanic and metamorphic terrain also contributed substantially because porphyritic, metamorphic, and volcanic rocks occur as coarse grains in sandstone and clasts in conglomerate. The following is a brief chronological review of the published comments of geologists who have considered this problem.

Review of Published Comments

Turner (1891, p. 395) noted that the conglomerates in the Upper Cretaceous of the Mount Diablo area " . . . contain numerous pebbles of metamorphic rocks and quartz porphyrite. These last pebbles are probably derived from the Sierra Nevada. Quartz porphyrite occurs abundantly in the foothills of Calaveras County. There are very few pebbles, however, of the red silicified shale of the Mount Diablo metamorphic area, which is so abundant. This would seem to indicate that the metamorphic rocks of the mountain were little exposed to erosion during the Chico epoch".

The composition of the conglomerates in the area north of Panoche Creek and their possible origin were discussed by Anderson and Pack (1915, p. 43):

> The great bulk of the pebbles are of a type of rock different from those exposed in the center of the Diablo Range, and the location of the land mass from which they were derived is problematic. Between Little Panoche and San Luis Creeks a very few of the larger and less rounded fragments are somewhat similar to the various igneous rocks exposed in the upper portion of the Franciscan formation in that vicinity and may possibly have been derived from it. In general, however, the lack of pebbles plainly indicating a derivation from the Franciscan rocks is a noteworthy feature of this formation.

Bruce L. Clark (1929, p. 226–227) studied the conglomerates on Quinto Creek and states that they " . . . contain boulders derived from the Franciscan, including chert and Franciscan igneous rocks of several types; with them are granitic and metamorphic rocks that can be matched with those of the Gabilan Mountains. A similar conglomerate is found above the Mount Diablo thrust on Puerto Creek".

Clark, along with Karl Rode, visited the Gabilan Range and collected rock specimens from the basal complex of that area and also rocks from the Franciscan Formation of the "Mount Hamilton Range". Clark states (p. 227):

> All of these were compared with the boulders in the Cretaceous conglomerates. It was found that the conglomerates were composed very largely of Franciscan rocks, other igneous rocks, and granitic boulders. A large part of the Mount Hamilton Range opposite the conglomerate localities studied is composed of igneous rock, and all the types of rocks found in the Franciscan here were found as boulders in the conglomerates. The granites of the southern Gabilan Range have a pink or reddish color and are very distinctive; specimens of this granite matched perfectly some of the boulders in the conglomerate.

The conglomerates in Quinto Creek were examined and commented on by Reed (1933, p. 101):

> A painstaking search at this locality through several conglomerate beds, including the thick basal conglomerate, failed to discover any distinctively Franciscan types of pebbles except a single one of red chert. A comparison of pebbles in this conglomerate with gravel in the beds of modern streams draining from the Franciscan rocks of the Diablo Range revealed the fact that the former lacks practically everything that occurs commonly in the latter.

In summary Reed states (p. 104): "The facts so far brought to light fail entirely to give aid and comfort to the holders of the hypothesis that upthrust Franciscan blocks contributed in any notable degree to the detritus of the Cretaceous sea". In an attempt to reconcile these divergent opinions Reed and Clark visited the Quinto Creek area, and Clark (1935), p. 1076) reports as follows:

> Reed, after again visiting Quinto Canyon in company with A. O. Woodford and the writer, agrees that the most common boulders in the conglomerates could not be distinguished from the igneous rocks that are found in the upper Franciscan, which is on the other side of the fault in the same section. He contends, however, that the Franciscan origin of the boulders is not proved because of the fact that certain of the distinctive Franciscan rocks are lacking in the conglomerate. For example, no boulders of serpentine or typical Franciscan sandstone were found, and red chert pebbles are rather scarce. His contention is that igneous rocks in the upper Franciscan on the opposite side of the fault, which rocks match the boulders in the conglomerate, are not distinctive and might not be distinguished from similar rocks in the Sierra Nevadas to the east.
>
> The answer to Reed's objection that distinctive rocks, such as sandtsones, serpentine, and glaucophane schists, are absent from this conglomerate is that these rocks were buried beneath the igneous rocks, which at the present time form the highest exposed outcrop in the Franciscan section, where they are standing vertically or nearly so . . . It is probable that over wide areas the original Franciscan rocks were buried under hundreds of feet of these igneous rocks. Thus during Cretaceous time, when the positive blocks were being uplifted, the debris that was carried by the streams was derived from these overlying rocks. The red and green cherts in the conglomerate indicate that the older Franciscan rocks were also exposed but probably not in the immediate vicinity.

Taliaferro (1944, p. 494–495) commented upon Reed's summary as follows: "However, the relatively large amount of Franciscan material in the Ascuncion conglomerates in the west part of the Santa Lucia Range and the east side of the Diablo Range is convincing evidence that, in some places, Franciscan areas contributed detritus to the Upper Cretaceous sea". He states that one such area was in the north-central part of the Diablo Range.

The composition of pebbles and boulders in conglomerates in Los Banos and Ortigalita Creeks, south of Pacheco Pass, were studied and commented on by Briggs (1953b, p. 30–31):

> One of the commonest components is porphyry which is not indigenous to the bedrock series of either the Coast Ranges or the Sierra Nevada, suggesting a western source for the bulk of the Upper Cretaceous sediment. Further support is lent by a northeasterly decrease in grain size of the coarser constituents of the conglomerate in Los Banos Creek, and an unconformity within the conglomerate sequence along Los Banos Creek in the northwest corner of Section 2, T.11 S., R.9 E., truncating uptilted strata of sandstone and siltstone which could only be deformed by lateral movement of the overlying conglomerate strata from west to east (figure 14, p. 27). Other boulders of the conglomerate are diorite, aplite, pegmatite, gneiss, schist and quartzite which are similar to rocks comprising the Sur series of the western Coast Ranges, and small amounts of greenstone, graywacke, and red chert are found that could have been derived from a Franciscan provenance. Thus there is considerable evidence supporting a western source for the conglomeratic strata.

Marshall Maddock (1964) described the conglomerates (principally Coniacian to Campanian) in the Mount Boardman quadrangle as follows:

> The conglomerates contain abundant pebbles of volcanic porphyry, as well as pebbles of chert, quartzite, acidic ond basic plutonic racks, aplite, pegmatite, sandstone, limestone, shale, schist and serpentine. The average pebble size is from 1 inch to 3 inches, but boulders os large as three feet ocross have been found. Some of the chert and sandstone pebbles are of obvious Fronciscon derivation. Hard calcoreous sandstone boulders contoining abundant molluscan fauna of Upper Cretaceous age are camman in the conglomerates, and these boulders are lithalogically similor to concretionory sondstone beds in the underlying part of the Panoche.

One of the characteristic features of the Franciscan is the presence of glaucophane schist. No published reports mention the existence of this rock type in the Cretaceous conglomerates of the Diablo Range. Collins (1950, p. 17) notes the occurrence of glaucophane rock in the conglomerates in the Orestimba quadrangle. Regarding their composition and source, he states:

> The only consistent character appears to be their compasition: charcateristically they (Panache conglamerates) contoin debris derived fram the Franciscan Formotion together with sandstane ond shale pebbles which conceivably could have been derived from the Horsetown and/or Panoche. The commonest pebbles and cobbles ore red, brown ond green chert, and in addition quortz, feldspar porphyry, sandstone, shale, glaucophone rock, ond various metosediments ond metavolconics ore present.

The conglomerates referred to by Collins occur above the Adobe Flat Member of the Panoche Formation and are probably no older than Coniacian.

Conclusions

The Campanian Age of the conglomerates along Del Puerto Creek may be quite important in an understanding of the stratigraphy and geologic history of the Upper Cretaceous. Since they occur some 13,000 feet below the top of the Panoche Formation, it would be easy to assume that they are correlative with the conglomerates that crop out prominently to the south, particularly along Quinto Creek. These latter conglomerates are older, however, being principally Turonian and Cenomanian. This age difference may have been unrecognized by Reed and Clark, and later by Taliaferro, and may have contributed to the confusion and arguments between them concerning the source of the Upper Cretaceous in the eastern Diablo Range. From personal observation it appears that the composition of the Cretaceous conglomerates along Quinto Creek bears little resemblance to the composition of pebbles now comprising the alluvium in the stream bed. Along Del Puerto Creek this difference is not so marked, owing principally to the presence of red and green chert in the Cretaceous conglomerates in these outcrops.

Along Del Puerto Creek the pebble imbrication within unit III, the structural relationships between unit III and unit II and the Cretaceous and Franciscan types of debris found within the conglomerates, when considered together, strongly suggest a western source. Many of the clasts, particularly the dark cherts and porphyries, are very similar to pebbles in the older Upper Cretaceous conglomerates and may represent reworked material. The red and green chert and other rocks not present in significant quantities in the older conglomerate beds may have been derived from the Franciscan Formation, which may have been exposed to the west for the first time during Coniacian to early Campanian time. The source of the older conglomerates which are well-exposed in Quinto Creek cannot be determined from examination of the rock units in the area covered by this report.

SUMMARY

The surface exposures of the Upper Cretaceous sedimentary rocks in the canyons of Hospital, Ingram, Del Puerto, and parts of Salado Creeks and the intervening areas have been studied. The relationships of these rocks to the surface exposures of Upper Cretaceous rocks to both the north and south of these exposures and in the subsurface to the east have been considered. The significant results of this study are:

1. The upper 5,000 feet of the Upper Cretaceous sedimentary rocks that crop out along Del Puerto Creek are correlative with the rock units encountered in numerous wells drilled in search of oil and gas in the northern San Joaquin Valley.

2. Most of the Upper Cretaceous Panoche Formation of this area was deposited in deep water by density or turbidity currents.

3. Detailed regional correlations are difficult or impossible because of abrupt lateral variations in lithology caused by facies changes and topographic irregularities on the floors of the basins of deposition, together with insufficient diagnostic fossils.

4. Too few paleocurrent indicators were found to give conclusive evidence as to current direction, but it appears that most of the depositional currents were moving parallel to the longitudinal axes of the basins in a northwest or southeast direction.

5. The axes of the basins of deposition progressively shifted from west to east during Late Cretaceous time.

6. The Upper Cretaceous, Campanian Stage, conglomerates had a western source and contain some clasts of Franciscan type rocks. Older Upper Cretaceous conglomerates contain little or no Franciscan type debris, and the direction of the source area or present location of their source could not be determined from this study.

7. The Moreno Formation was deposited in a relatively shallow-water, near-shore environment, and a land mass stood to the west of the present outcrop of the Moreno Formation, probably in the area now occupied by a part of the Diablo Range.

8. The deeper parts of the sedimentary basins during the time of Moreno deposition were east of the present outcrop area, the area now occupied by the San Joaquin Valley.

9. Stratigraphic-structural traps for oil and gas may exist along the margins of these basins as a result of buttressing and overlapping of sands and subsequent folding and/or faulting.

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APPENDIX

Microfossils collected by the writer during the course of this investigation. For location see plate 1.

DP-108 Upper Cretaceous, E zone of Goudkoff.
- *Planulina constricta* R
- *Silicasigmoilina californica* C
- *Gaudryina bentonensis* R
- *Bathysiphon vitta* C
- *Trochammina* sp. cf. *T. texana* VR
- *Epistomina caracalla* VR
- *Bulimina kickapooensis* VR

DP-302 Upper Cretaceous, E zone of Goudkoff.
- *Planulina constricta* R
- *Marssanella oxycona* VR
- *Bulimina* sp. C
- *Silicosigmoilina californica* R
- *Bathysiphon vitta* VR

DP-403 and 404 Upper Cretaceous, C and/or D-1 zone of Goudkoff.
- *Bulimina prolixa* F

DP-707 Upper Cretaceous, probably D-2 zone of Goudkoff.
- *Bulimina joaquinensis* VR
- *Radiolaria* sp. C.

DP-715 Upper Cretaceous, probably D-2 zone of Goudkoff.
- *Bulimina joaquinensis* VR
- *Gyroidina* sp. VR
- *Radialaria* sp. VR
- *Inoceramus* prisms C
- Sponge spicules C

ING-101 Upper Cretaceous, D-1 zone of Goudkoff.
- *Bulimina prolixa* C
- *Siphogenerinoides clarki* VR

ING-120 Upper Cretaceous, E zone of Goudkoff.
- *Planulina constricta* R
- *Bathysiphon vitta* R
- *Silicosigmoilina californica* R
- *Inoceramus* prisms C

HOS-1 and HOS-103 Upper Cretaceous, D-1 zone of Goudkoff.
- *Siphogenerinoides clarki* R
- Sponge spicules C
- *Bulimina* cf. *B. spinata* VR

HOS-2 Upper Cretaceous, E zone of Goudkoff.
(Telephone communication 1964, no check-list was obtained, sample contains *Planulina constricta*)

HOS-113 Upper Cretaceous, E zone of Goudkoff.
Planulina constricta (fragment)
Cribrostomoides cretacea C
Gaudryina bentonensis VR
Bathysiphon vitta C

HOS-129 Older than Campanian.
No check-list was obtained; this sample is in close proximity to the occurrence of *Cibicides stephensoni* first reported by Goudkoff (1945, p 993) and referred by him to the G-2 zone

BG-101 Upper Cretaceous, probably D-2 zone of Goudkoff
Bulimina joaquinensis C
Gyroidina sp VR
Nodosaria spinifera C
Radiolaria sp VR
Inoceramus prisms C
Sponge spicules C

SOL-111 Upper Cretaceous, D-2 zone of Goudkoff.
Bulimina joaquinensis VR
Radiolaria sp. C
Nodosaria velascoensis VR

In addition to the above samples collected by the writer, the following information was obtained from Charles W. Cary (personal communication, 1964): In Hospital Creek approximately 350 feet stratigraphically below HOS-1 and HOS-103, the shales contain *Bolivina incrassata* and *Nodosaria spinifera* which belong to Goudkoff's D-2 zone. Samples from a shale bed about 610 feet below the top of the Panoche in Ingram Creek contain the Goudkoff E zone marker *Planulina constricta*.

Abbreviations:
C—Common
F—Few
R—Rare
VR—Very Rare

Megafossils collected by Maddock (1955). Identification and age assignments by LouElla Saul 1967.

Univ. Calif., Berkeley loc. B-761
Mt. Boardman quad., WDCE 1952 1/62500 [973500-1627190 : 37.1°N, 121.1°W]
Acila demessa Finlay
Glycymeris veatchii (Gabb)
Pteria cf. *P. pellucida* (Gabb)
"*Trigonia leana*" group sp. indet.
Pterotrigonia evansana (Meek)
Platymya cf. *P. subcylindracea* (Whiteaves)
Meekia (Mygallia) mygale Saul & Popenoe
Calva cf. *C. taffi* (Anderson)
Tellina (Tellinella) n. sp.—as from Santonian of Chico Fm., Chico Creek
Tellina ashburnerii (Gabb)
Cymbophora cf. *C. gabbiana* (Anderson) coarse ribbed form
Cymbophora aff. *C. gabbiana* (Anderson) fine ribbed form
Martesia?
Margarites ornatissimus (Gabb)
Lysis aff. *L. duplicata* (Gabb)
Volutoderma cf. *V. gabbi* (White)
Biplica heteroplicata Popenoe
sharks teeth
age: Santonian

Univ. Calif., Berkeley loc. B-765
Mt. Boardman quad., WDCE 1952 1/62500 [970200-1622420 : 37.1°N, 121.1°W]
Glycymeris veatchii (Gabb)
Meekia louella Popenoe
Calva cf. *C. taffi* (Anderson)
Gyrodes n. sp.—as from member IV of Redding area
Biplica cf. *B. heteroplicata* Popenoe
age: Coniacian

Univ. Calif., Berkeley loc. B-766
Mt. Boardman quad., WDCE 1952 1/62500 [970150-1621780 : 37.1°N, 121.1°W]
Glycymeris pacifica (Anderson)
Meekia radiata (Gabb)
Calva regina Popenoe
age: Turonian

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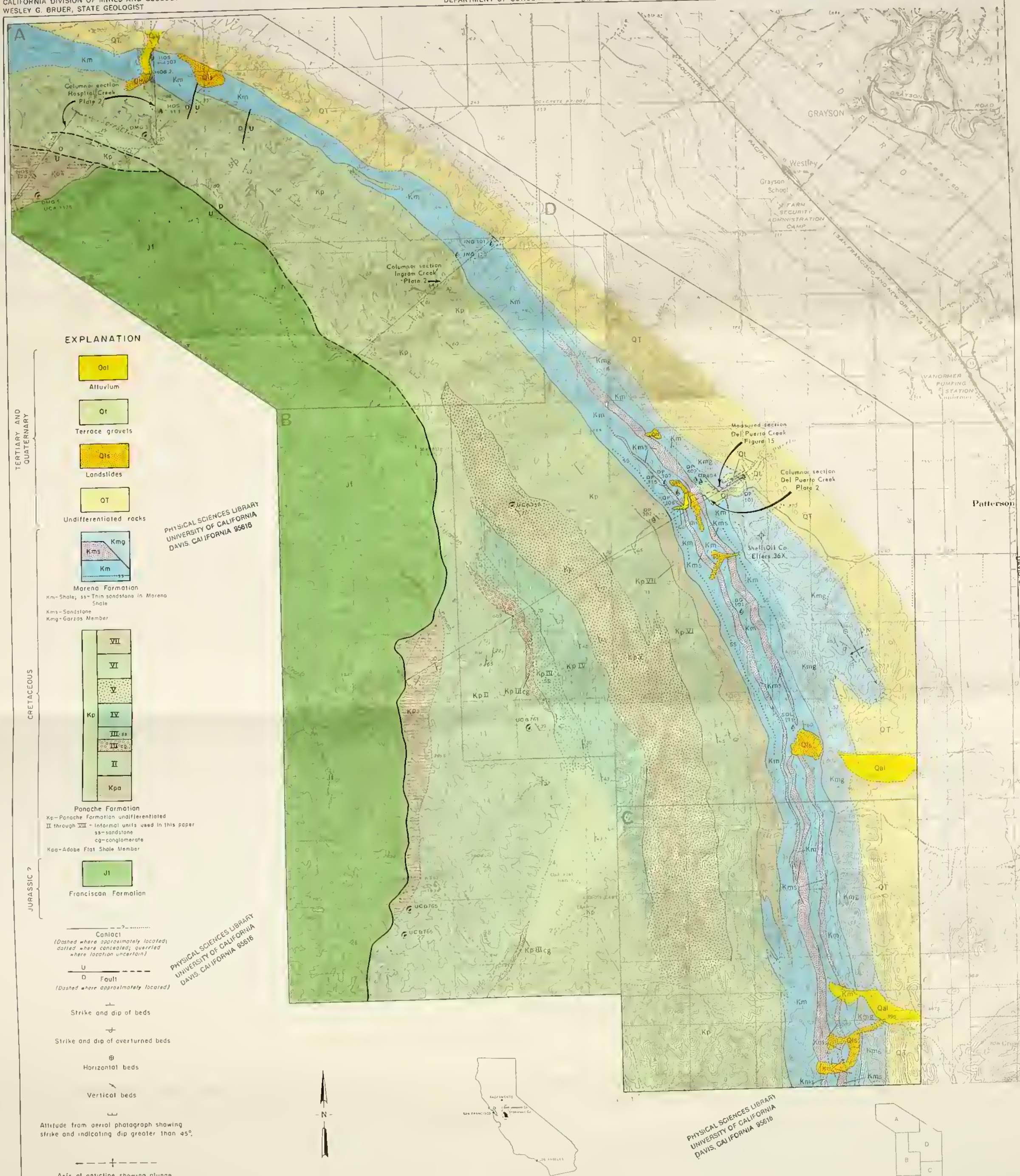

EXPLANATION

TERTIARY AND QUATERNARY

- Qal — Alluvium
- Qt — Terrace gravels
- Qls — Landslides
- QT — Undifferentiated rocks

CRETACEOUS

- Km, Kms, Kmg — Moreno Formation
  - Km – Shale; ss – Thin sandstone in Moreno Shale
  - Kms – Sandstone
  - Kmg – Garzas Member
- Kp — Panoche Formation
  - Kp – Panoche Formation undifferentiated
  - II through VII – informal units used in this paper
  - ss – sandstone
  - cg – conglomerate
  - Kpa – Adobe Flat Shale Member

JURASSIC ?

- J1 — Franciscan Formation

Contact
(Dashed where approximately located; dotted where concealed; queried where location uncertain)

U / D Fault
(Dashed where approximately located)

Strike and dip of beds

Strike and dip of overturned beds

Horizontal beds

Vertical beds

Attitude from aerial photograph showing strike and indicating dip greater than 45°.

Axis of anticline showing plunge

Microfossil locality
Division of Mines and Geology

Megafossil locality
DMG = Division of Mines and Geology
UC = University of California

Well location

Columnar sections along Hospital, Ingram and Del Puerto Creeks.

Measured section along Del Puerto Creek

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GEOLOGIC MAP OF THE UPPER CRETACEOUS ON THE WEST SIDE OF THE NORTHERN SAN JOAQUIN VALLEY, STANISLAUS AND SAN JOAQUIN COUNTIES, CALIFORNIA

BY
CHARLES C. BISHOP
1970

INDEX TO GEOLOGIC MAPPING

A. Modified in part from San Jose State College student mapping under the direction of M. E. Maddock, unpublished, 1960-61

B. Modified in part from Maddock, 1964.

C. Modified from Booth, 1950.

D. Mapped by C. C. Bishop, 1963-65.

SCALE 1:62,500

TOPOGRAPHIC BASE MAP BY U.S.G.S.

DRAFTED BY HUGO H. HAWKINS

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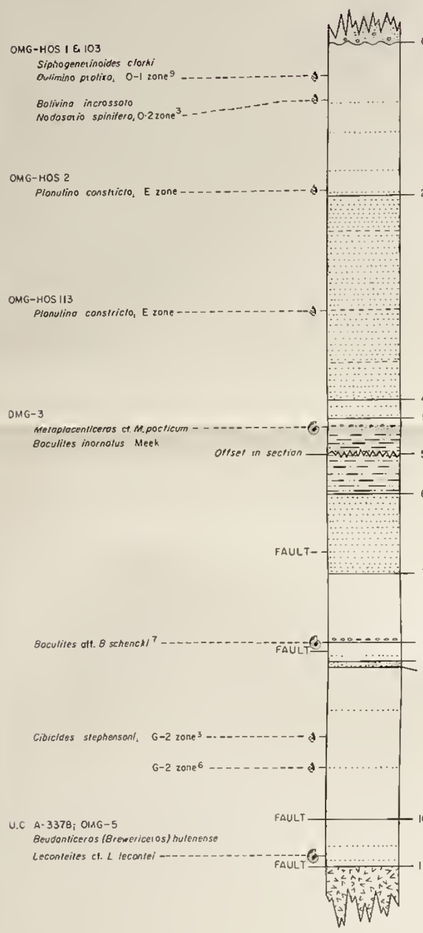
HOSPITAL CREEK



Lithologic Description

SANDSTONE, light gray with a blue cast, firm to easily friable, irregularly bedded in beds from a foot or two to 10 feet in thickness. The grain size varies greatly from bed to bed but individual beds are fairly well sorted. Some beds are fine to very fine grained, silty and clayey, while others are coarse to very coarse grained with pebbles from one-half to one inch in diameter. Individual grains are very commonly quite magnetic and represent fragments of volcanic rock (andesite) composed of plagioclase, volcanic glass, hornblende, and magnetite. The magnetic properties are quite distinctive and may be useful in local or regional correlations. The blue color appears to be caused by a thin coating on many of the grains.

MORENO FORMATION
CLAYSTONE, medium dark gray weathering to chocolate brown with a purple cast, thinly bedded, occasionally fissile, firm, commonly silty, common carbonaceous material, abundant selenite, occasional fish scales, locally abundant well preserved forams. The unit contains several interbeds, five to ten feet thick of arkosic sandstone, light to medium gray weathering to buff, firm to friable, fine to medium grained and silty. The lower contact is gradational and the lower 150 to 200 feet contain numerous thin beds of sandstone, medium to light gray, thinly bedded to platey, fine grained, silty with abundant biotite. The claystone is cut in several places by dikes of sandstone, medium gray weathering to dirty buff brown, fine grained, very silty to clayey, feldspathic with common dark metamorphic rock grains.

PANOCHE FORMATION (Upper and Lower Cretaceous, undifferentiated)
SANDSTONE, light gray weathering to buff, hard to locally somewhat friable, generally in beds from one to four feet thick but occasional beds to 10 feet, fine to medium grained, silty to clayey, scattered biotite, arkosic, occasionally contains small fragments of carbonized wood, common ferruginous and calcareous spheroidal and elliptical concretions to a few feet in diameter. Contains occasional interbeds of siltstone and claystone, medium gray to gray brown, thinly bedded, locally fissile, fine grained sandy, common carbonaceous material, rarely contains foraminifera. Sedimentary structure at the tops of the beds is less common than in Ingram or Del Puerto Creek. In many cases the upper parts of the turbidites appear to have been eroded prior to deposition of the succeeding bed.

SILTSTONE, medium brown, firm, thinly bedded, clayey, very fine grained sandy, scattered finely divided carbonaceous material, contains occasional interbeds from one to six inches in thickness of very fine grained silty sand. And:
SANDSTONE, similar in appearance and lithology to that in unit above. The unit is composed of 70 feet siltstone, 40 feet sandstone, 61 feet siltstone, and 65 feet sandstone; a total of 240 feet.

SILTSTONE and SILTY SANDSTONE, rhythmically bedded generally in beds from an inch or two inches in thickness.
SILTSTONE, medium brown, firm, thinly bedded, occasionally laminated, clayey, locally very abundant carbonaceous material.
SILTY SANDSTONE, brownish gray, firm to somewhat friable, very fine grained, generally in beds an inch or two in thickness but occasionally up to a foot thick. Commonly contains dark laminae of coarser grained sand, and laminae of carbonaceous material. Sedimentary structures indicate deposition by turbidity currents.
A fossiliferous conglomerate to two feet in thickness occurs 130 feet from the top of the unit. Pebbles of siltstone and chert generally an inch or two but ranging to four inches in diameter are most common. Calcareous concretions often containing fossils are numerous. The matrix is composed of sandy claystone with abundant shell fragments. Baculites comprise most of the fossil material; however, the ammonite, *Metaplacenticeras* cf. *M. pacificum* was identified.
The lower 375 feet of this unit becomes increasingly sandy toward the base. These sands are generally thinly bedded as above, but a few beds to five feet in thickness are present.

SILTSTONE, medium gray brown weathering to chocolate brown, thinly bedded, firm, clayey to very fine sandy, scattered carbonaceous material, contains occasional calcareous shale concretions.

SANDSTONE, medium light gray, hard to somewhat friable, in beds from a few inches to a foot or so in thickness, fine to medium grained, silty.

CLAYSTONE, medium dark gray to locally grayish brown, firm, thinly bedded, commonly silty, scattered finely divided carbonaceous material. The base of this unit is marked by a fossiliferous
CONGLOMERATE, consisting of two beds each about three feet in thickness and separated by several feet of claystone. The conglomerate consists principally of siltstone pebbles one-half to one inch and rarely three inches in diameter. Abundant pelecypods and gastropods shells and shell fragments occur in a matrix of very coarse grained sandy, clayey siltstone. No ammonites were recovered.*

CLAYSTONE, medium dark gray brown with a green cast, thinly bedded in beds to an inch or so in thickness, silty, commonly grading to a clayey siltstone, scattered finely divided carbonaceous material. This unit contains occasional interbeds an inch or so in thickness of:
SANDSTONE, light gray, hard, dense, fine grained calcareous, very silty, rare carbonaceous material.

SANDSTONE, medium greenish gray weathering to buff, thinly bedded at the top in beds generally six inches to a foot in thickness, fine grained, silty, calcareous, dense, common biotite, occasional fragments of carbonaceous material, well indurated.

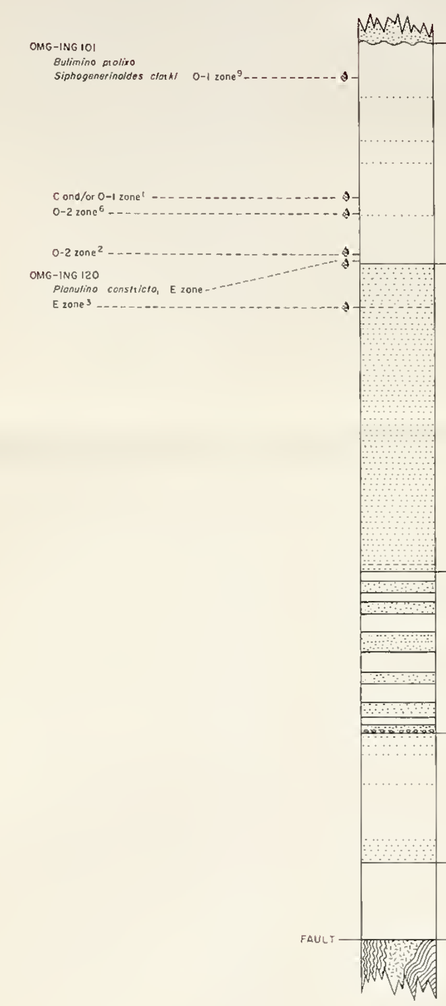
CLAYSTONE, medium gray brown with an olive green cast, firm to hard, thinly bedded, concoidal fracture, common calcareous concretions, silty to fine grained sandy, scattered finely divided carbonaceous material, occasional interbeds of:
SANDSTONE, medium gray, hard, in beds an inch or two in thickness, fine grained, well sorted, calcareous, tight.

CLAYSTONE, medium to dark greenish gray, darker in appearance than above, hard, brittle, siliceous, thinly bedded, contains occasional fine grained sandy conglomeratic beds that are occasionally fossiliferous, the upper contact is a fault. The lower sandstones, one of which contains a good fauna of pelecypods, *Pecten* cf. *P. operculiformis* (Cahl) and occasional ammonites, are medium dark greenish gray, hard, well indurated, medium grained with scattered coarse grains, silty to clayey, chloritic, minor calcite cement, common dark mineral and metamorphic rock grains, with quartz and feldspar, common to locally abundant silicified wood.

FRANCISCAN FORMATION
Volcanic rocks.

* Loren A. Raymond (written communication, 1968) reports *Baculites* aff. *B. Scherchi* Matsumoto.

INGRAM CREEK



MORENO FORMATION
CLAYSTONE, medium dark gray to gray brown, weathering to chocolate brown with a purple cast, firm, thinly bedded to locally fissile, commonly silty to very fine grained sandy, locally abundant selenite, common carbonaceous material, locally abundant forams. The unit contains numerous thin interbeds of sandstone generally a foot or two in thickness, and separated by 50 to 100 feet of shale. The sandstones are medium dirty gray brown, firm to friable, fine grained, silty to clayey with common small ferruginous concretions an inch or two in diameter.

PANOCHE FORMATION (undifferentiated)
SANDSTONE, medium light gray to medium dark gray weathering to buff, thickly bedded in beds varying from a foot to more than ten feet in thickness, firm to hard, occasionally calcareous, common calcareous and ferruginous concretions to several feet in diameter, fine grained, generally silty, arkosic with scattered dark metamorphic rock grains. Occasional fragments of carbonaceous material, contains occasional streaks or laminae of darker colored fine grained silty to clayey material that contains scattered black carbonaceous fragments. The unit is composed almost entirely of sandstone with the exception of a seven-foot bed of claystone which occurs about 625 feet from the top of the unit. The longitudinal axis of load waves and load casts indicate current flow from northeast or southwest. These and other sedimentary features suggest deposition by turbidity currents.

INTERBEDDED SANDSTONE, SILTSTONE AND CLAYSTONE
SILTSTONE and CLAYSTONE, medium gray brown, firm, thinly bedded, clayey, scattered finely divided carbonaceous material, fine grained sandy, commonly contains interbeds of fine grained sandstone.
SANDSTONE, medium light gray, in beds from a few inches to two or three feet in thickness with common laminae of carbonaceous clay and silt, fine grained to medium coarse grained, silty. Thicker non-laminated beds contain ferruginous concretions from six inches to a foot in diameter. Sedimentary structures indicate deposition from turbidity currents.
The base of this unit is marked by a thin conglomerate bed about seven feet thick, composed of pebbles from an inches to about one foot in diameter of metamorphic and igneous rocks, principally quartz and feldspar porphyry, and some pebbles of calcareous shale and coarse sandstone.

CLAYSTONE AND SILTSTONE, WITH INTERBEDDED SANDSTONE
CLAYSTONE and SILTSTONE, dark gray to dark gray brown, in beds a few inches to a foot in thickness, firm, abundant carbonaceous material, common selenite interbedded with:
SANDSTONE, light gray, generally in beds a foot or two feet in thickness with one or two beds to 15 feet, firm to friable, fine to very fine grained to locally medium grained, arkosic, common biotite, silty, common thin interbeds and laminae of carbonaceous siltstone.
The unit becomes increasingly sandy toward the base and grades to:
SANDSTONE, medium gray, firm to friable, generally thinly bedded in beds from about one inch to a maximum of about a foot in thickness, non-concretionary, fine to very fine grained, but increasing in coarseness to medium grained at base, arkosic, silty, common biotite and scattered muscovite.

CLAYSTONE, dark gray, firm, silty to very fine grained sandy, with occasional interbeds from about six to 18 inches of sandstone, light medium gray, firm to hard, fine grained, silty with low permeability, rare thin coarse grained, calcareous sandstone beds.

Franciscan Formation, glaucophane schist, greenstone, amphibolite schist and chert.

EXPLANATION

- Claystone
- Claystone interbedded with sandstone
- Claystone and/or siltstone with interbedded sandstone
- Siltstone and sandy siltstone
- Sandstone
- Conglomerate
- Volcanic rocks
- Metamorphic rocks, schist and chert
- Division of Mines and Geology foraminifera locality
  - OP = Del Puerto Creek
  - HOS = Hospital Creek
  - ING = Ingram Creek
- Megafossil locality
  - DMG = Division of Mines and Geology
  - U.C. = University of California, Berkeley
  - CAS = California Academy of Sciences
- Palynomorph and/or Dinoflagellate locality

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9. Zones refer to Goudkoff's zonation of the Upper Cretaceous: A.A.P.G. Bull., Vol. 29, pp. 956-1007.

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COLUMNAR SECTIONS OF THE UPPER CRETACEOUS ON THE WEST SIDE OF THE NORTHERN SAN JOAQUIN VALLEY, STANISLAUS AND SAN JOAQUIN COUNTIES, CALIFORNIA

By
CHARLES C. BISHOP

1970

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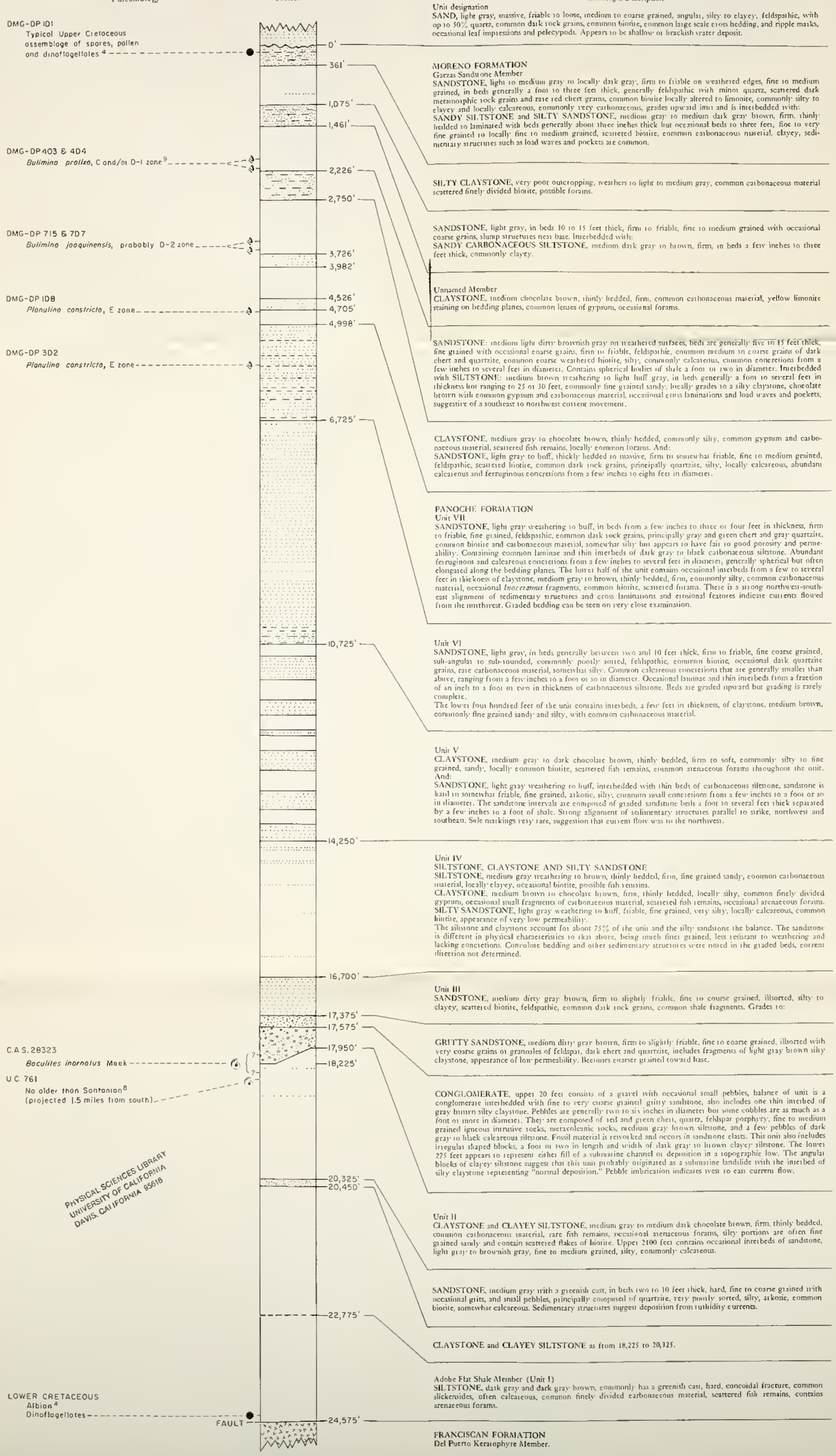
DEL PUERTO CREEK



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